HOW THE ASTEROID BELT FORMED

HOW IT WORKS

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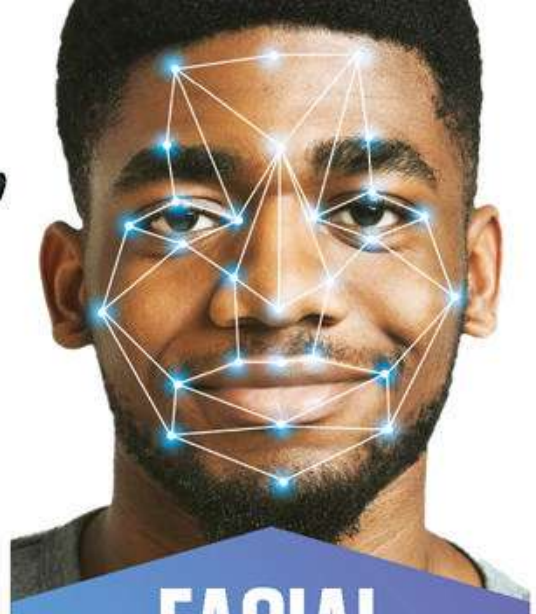

FACIAL RECOGNITION EXPLAINED

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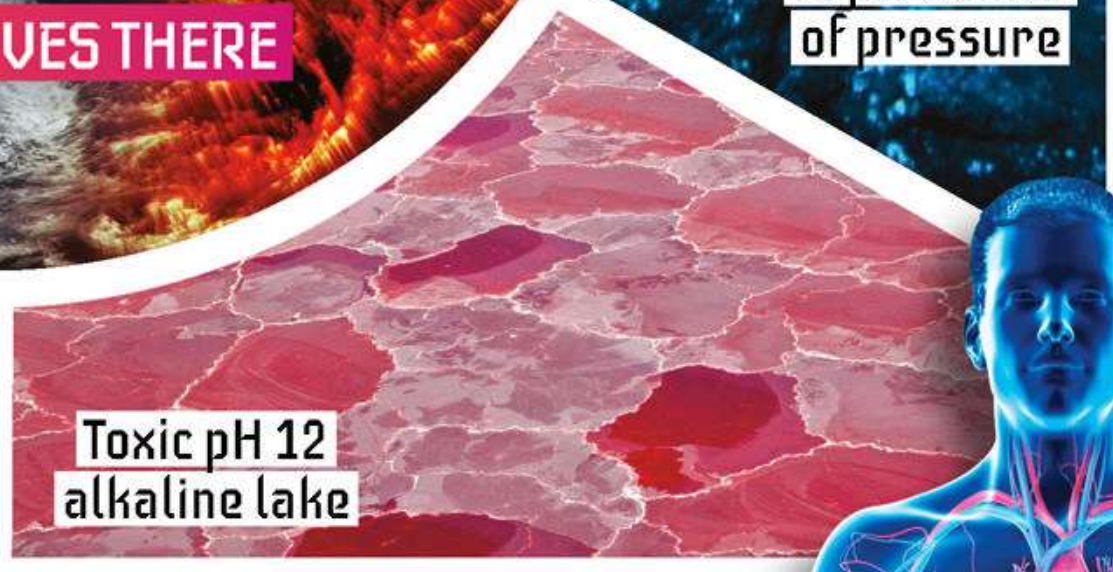
> WHY NETTLES STING

> RIP CURRENTS EXPLAINED

> MONSTER VEHICLES

EXTREME EARTH

EXPLORE THE MOST HOSTILE PLACES ON THE PLANET AND LEARN HOW LIFE SURVIVES THERE



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Issue 174

"This place is as deadly as it is mesmerising"

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See inside this monster nuclear submarine

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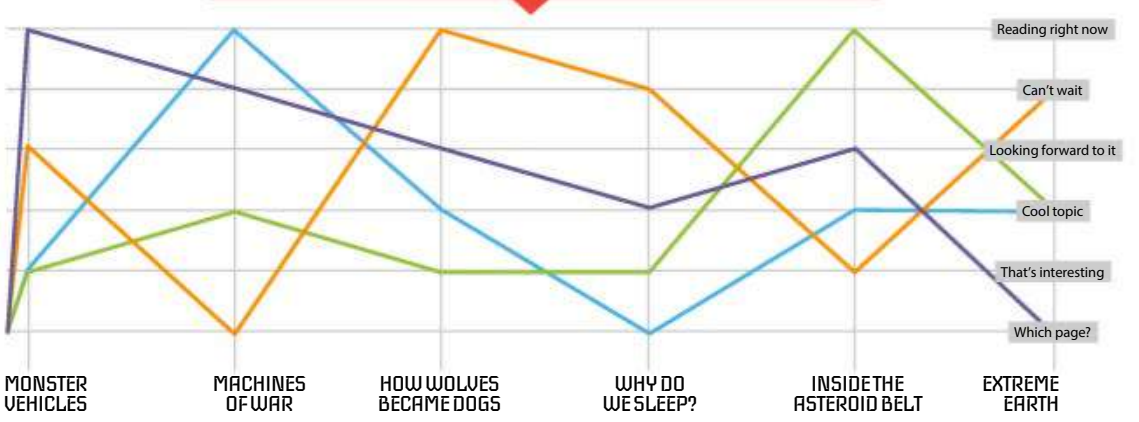
The stunning alien-looking scene above is the Dallol geothermal field in Ethiopia. It's an extremely saline and hyperacidic hydrothermal site found in the hellish landscape of the Danakil Depression, which we've included in our cover feature this issue. The difference between this site and the rest of the Danakil Depression is that the pools are so hot, salty and acidic that no life has been found here whatsoever – not even the salt-hungry microorganisms that survive in other parts of the depression. It's one of the few natural environments on Earth we know of where life can't survive, and it's studied by researchers to help them understand the limits of habitability, as well as how life could form on other planets. Enjoy!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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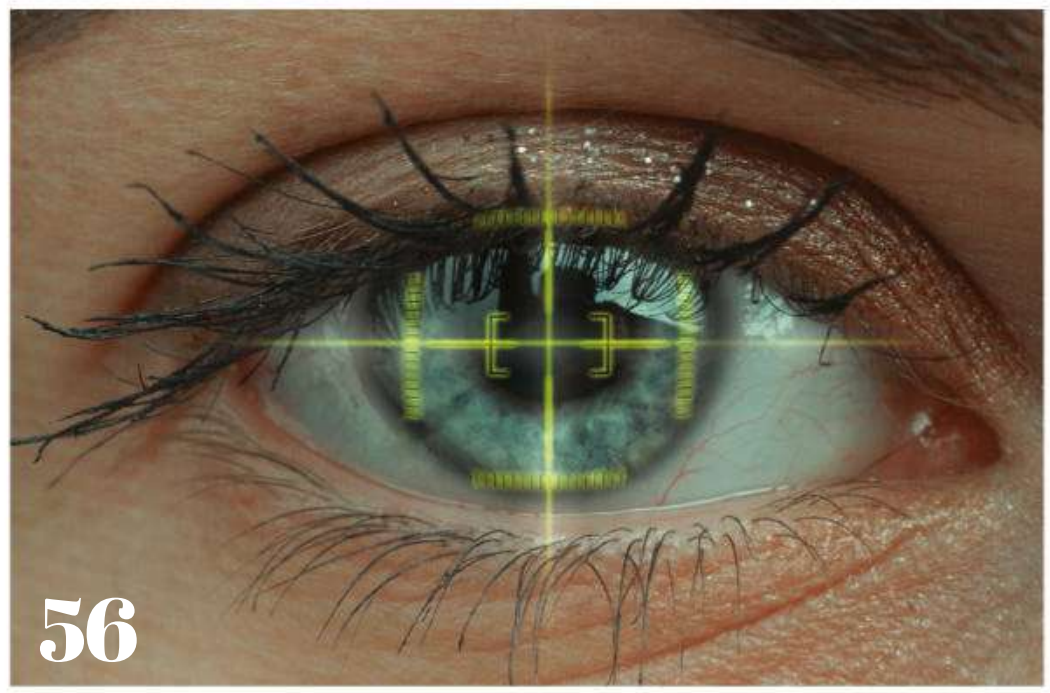

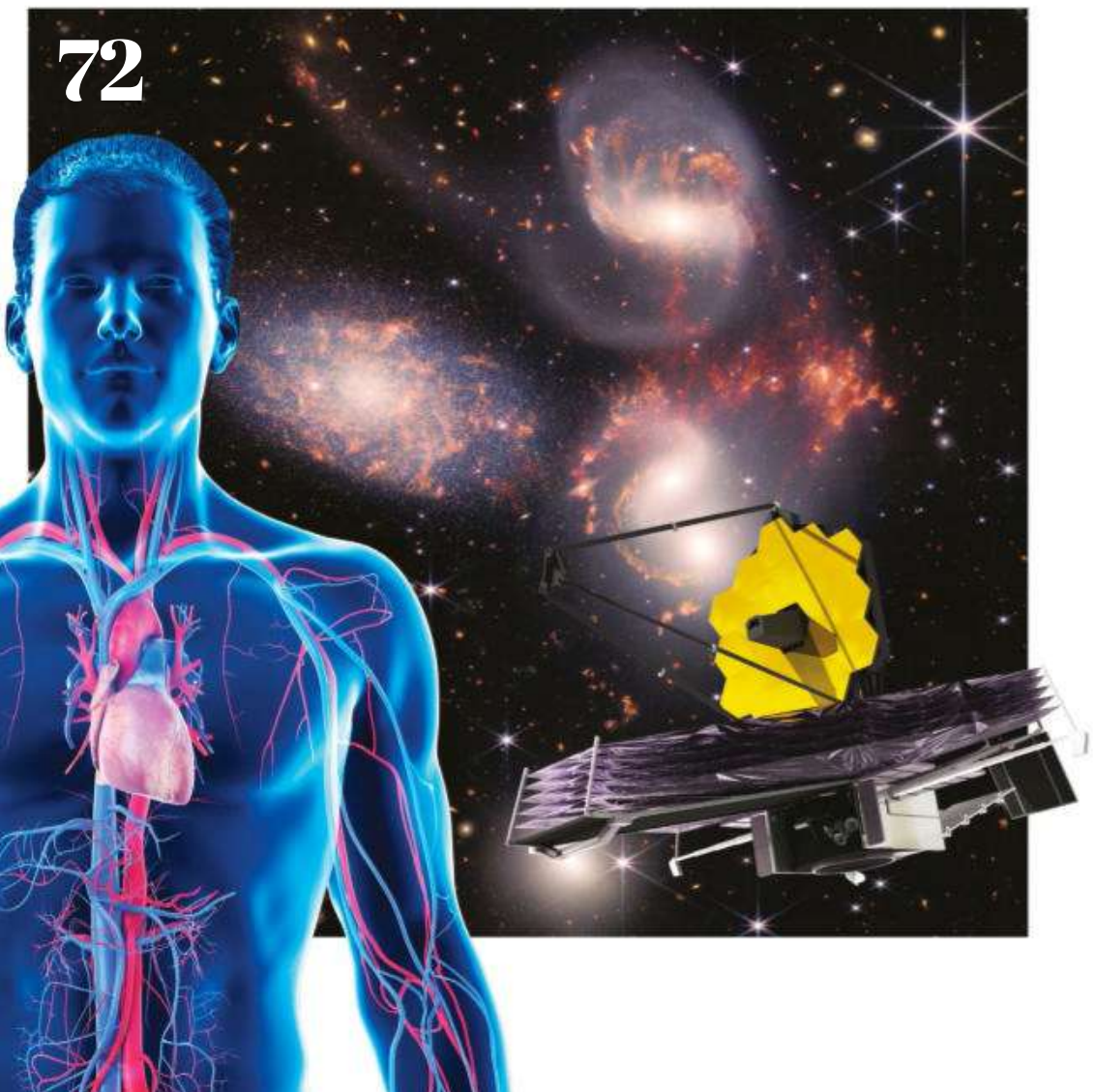

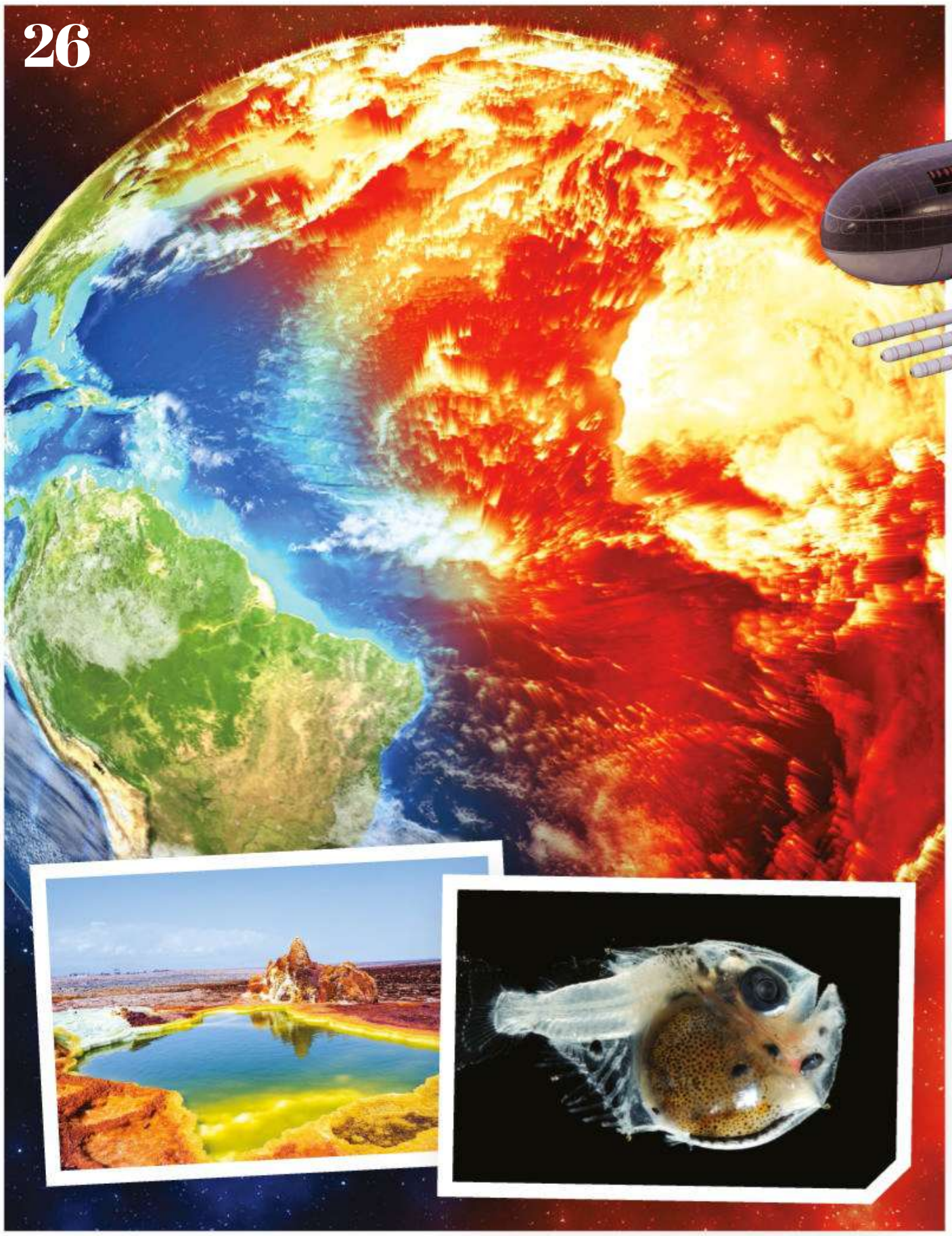
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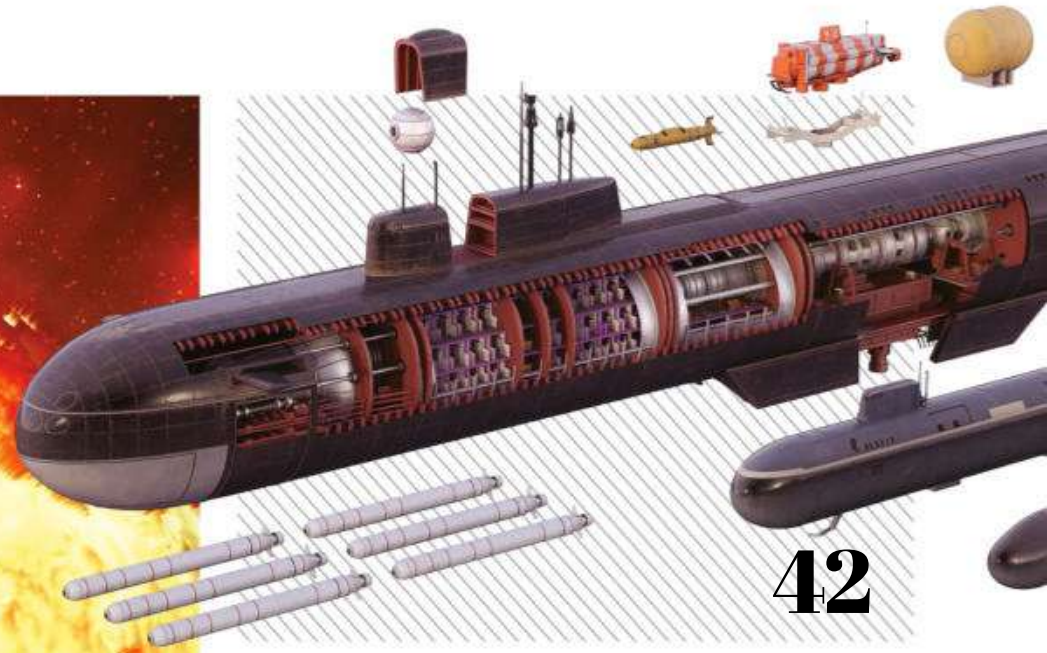
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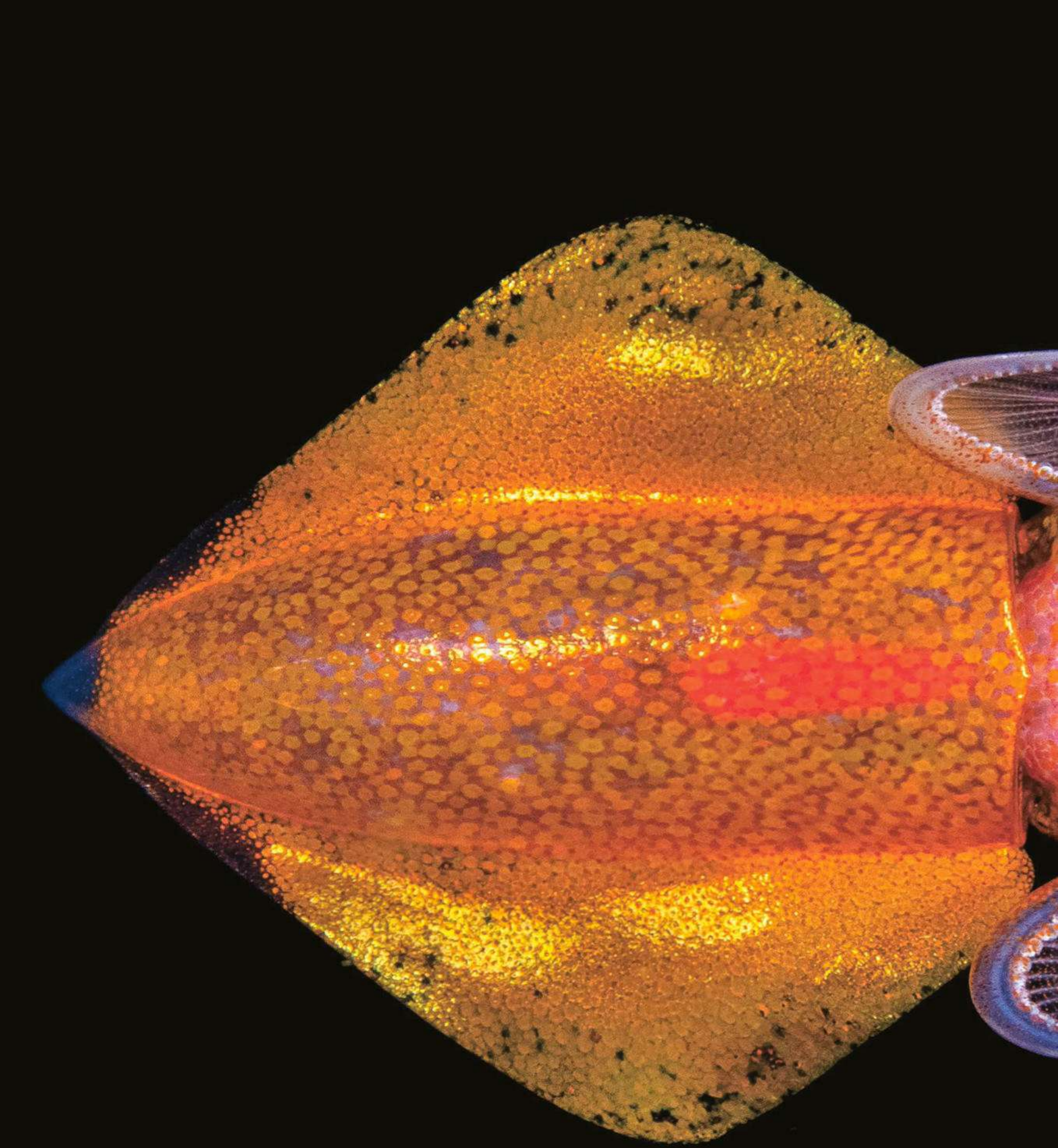


Deep-sea squid

Diamond squid (*Thysanoteuthis rhombus*) don't have light organs, instead using their colour-changing bodies to communicate with one another. This vibrant specimen made an appearance during a blackwater dive in Anilao, Philippines. Blackwater diving is a form of scuba diving that's carried out during the dead of night – a dark journey up to a hundred metres below the surface.

© Alamy

Cosmic clouds

The James Webb Space Telescope has snapped another astonishing photograph of the deep sky. These cosmic clouds form a gaseous cavity within the star-forming Carina Nebula, also known as NGC 3372. The cavity has been carved through intense ultraviolet radiation, creating tall peaks – the tallest of which is around seven light years high.

© NASA, ESA, CSA, STScI, J. DePasquale (STScI)

Coronavirus under the lens

This is a colourised scanning electron microscope image of a coronavirus infection. In the image, healthy cells (pink) have been heavily infected with severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) particles (teal and purple) from a patient sample. Spikes coating the surfaces of SARS-CoV-2 particles hook onto receptors in healthy human cells during infection.

© Getty

Lunar rainbow

At the base of the cascading Skógafoss waterfall in Iceland is a shallow rainbow known as the moonbow. This optical phenomenon occurs when moonlight is refracted through the droplets of the waterfall. The colours can't always be seen because of a lack of light falling on the colour receptors in the human eye. However, as seen in this image, a long exposure can reveal the rainbow.

© Alamy

SPACE

Mysterious Sun 'sparks' help scientists predict solar flares

WORDS JOANNA WENDEL

Solar flares, powerful bursts of radiation from the Sun, are often preceded by a pre-flare spark. The finding could lead to better predictions of solar storms, which can disrupt power grids and communications systems on Earth. Scientists made the discovery after digging into years of data from NASA's Solar Dynamics Observatory (SDO), a satellite that's been observing the Sun since 2010. Since the 1970s and 1980s, researchers had witnessed these pre-flare flashes using tools such as ground-based observatories, so there was a lot of anecdotal evidence that the flashes and flares were related. But those researchers didn't have instruments like SDO, which is constantly watching and recording the Sun's activity from space.

"Images of [the Sun] have definitely been helping scientists and forecasters understand when an active region is likely to be flare-productive," said K. D. Leka, a senior research scientist at NorthWest Research Associates (NWRA) in Boulder, Colorado. Leka and her team combed through nearly a decade of SDO data, zooming in on active regions of the Sun known as sunspots. These dark areas are places where the Sun's magnetic field is particularly active due to contortions deeper within the star. The contortions cause the Sun's magnetic field to twist and tangle. And when those magnetic field lines snap back into their original form, an enormous burst of energy erupts from the surface. These explosions can manifest as either a solar flare or a coronal mass ejection (CME). Solar flares are intense surges of X-rays and energy that shine in all directions. The electromagnetic energy moves at the speed of light and can arrive at Earth within eight minutes. CMEs, by contrast, are explosions of highly charged particles that erupt in a particular direction. They move more slowly, at 155 to 1,900 miles per second; it can take several days for a CME to sweep over Earth. Both kinds of explosions can cause damage to power systems and telecommunications on Earth, but they are generally harmless to humans and other living things.

In thousands of terabytes of data from SDO, Leka and her team found that solar flares are often associated with a moment of brightness, like when you strike a match and it sparks before igniting. These sparks occurred up to one day before flares erupted from the same region of the Sun.

> "The finding could lead to better predictions of solar storms"

The findings, while exciting for our understanding of solar physics, do not mean that scientists can now predict solar flares, Leka explained. Think of it like forecasting a volcanic eruption – earthquakes near an active volcano tell scientists that underground magma is on the move and could be leading to an eruption. So scientists monitor earthquakes and tweak models to predict when an eruption might occur. But no single earthquake is a predictor of a volcanic eruption.

"Down the road," said Karin Dissauer, a research scientist at NWRA, "combining all this information from the surface up through the corona [the Sun's outer atmosphere] should allow forecasters to make better predictions about when and where solar flares will happen."

HEALTH

WORLD'S OLDEST PERSON DIES AT 118

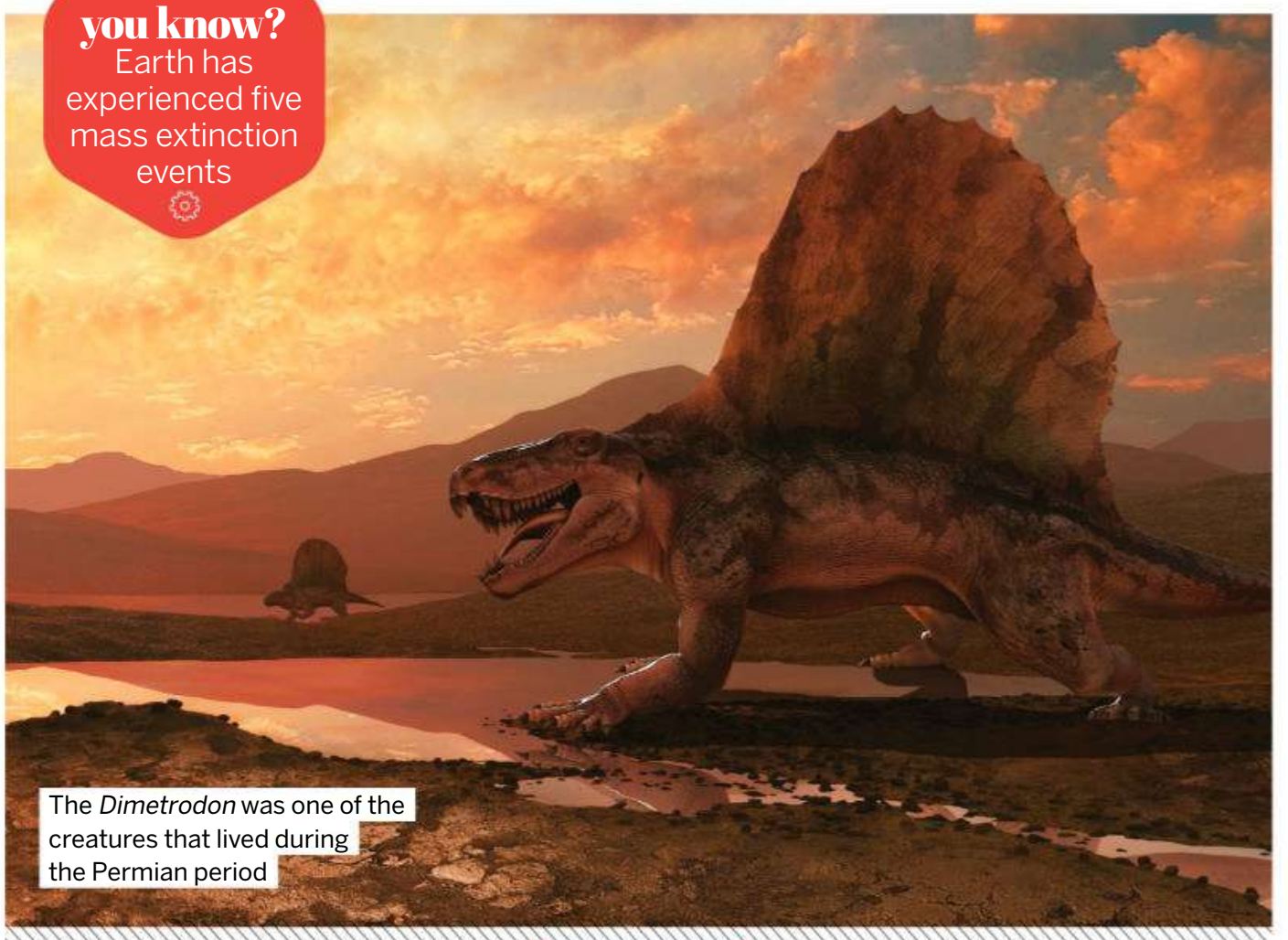
WORDS JENNIFER NALEWICKI

Sister André, a French nun who held the title of the world's oldest person, died on 17 January at age 118 in Toulon, a city in southern France. Born Lucile Randon on 11 February 1904, Guinness World Records declared Sister André not only the world's oldest person but also the oldest nun on record. She earned the former title in April 2022 after the passing of Kane Tanaka, a 119-year-old Japanese woman. Sister André was also the oldest person in Europe to survive COVID-19, being released from the hospital in time to celebrate her 117th birthday. "I didn't even know that I had it," Sister André told *Var-Matin*, a French newspaper.

For anyone hoping to reach a similar age as Sister André, eating high-quality dark chocolate may have a few health benefits, such as protecting against heart failure in women and possibly lowering blood pressure and decreasing the risk of stroke. However, while wine may protect against a few health conditions, such as lowering the risk of heart disease, there isn't much evidence suggesting it may lead to a longer life. Sister André was three years shy of earning the title of the oldest person ever to live on record, held by Jeanne Louise Calment, a fellow Frenchwoman who died on 4 August 1997 aged 122.

Sister André, the fourth-oldest person on record at 118 years and 340 days

Did you know?
Earth has experienced five mass extinction events



The *Dimetrodon* was one of the creatures that lived during the Permian period

HISTORY

Ultraviolet radiation played a role in a mass extinction event

WORDS JENNIFER NALEWICKI

A lethal pulse of ultraviolet (UV) radiation may have played a role in Earth's biggest mass extinction event, revealed by fossilised pollen grains. Pollen that dates to the time of the Permian-Triassic mass extinction event, roughly 250 million years ago, produced 'sunscreen' compounds that shielded against harmful UV-B radiation, an analysis found. At that time, approximately 80 per cent of all marine and terrestrial species died off. For the study, researchers developed a new method of using a laser beam to examine the miniscule grains, which measure about half the width of a human hair and were found embedded onto rocks unearthed in southern Tibet.

Plants rely on photosynthesis to convert sunlight into energy, but they also need a mechanism to block out harmful UV-B radiation. "As UV-B is bad for us, it's equally as bad for plants," said Barry Lomax, a professor in plant palaeobiology at the University of Nottingham. "Plants can alter their chemistry and make their own equivalent version of sunscreen compounds. Their chemical structure acts to dissipate the high-energy wavelengths of UV-B light and stops it from getting within the preserved tissues of the pollen grains." In this case, the radiation spike didn't "kill the plants outright, but rather it slowed them down by lessening their ability to photosynthesise, which caused them to become sterile over time," Lomax said. "You then wind up with extinction driven by a lack of sexual reproduction rather than the UV-B frying the plants instantly."

Experts have long thought that the Permian-Triassic extinction, classified as one of the five major extinction events on Earth, was in response to a 'palaeoclimate emergency' caused by the Siberian Traps eruption, a large volcanic event in what is now modern-day Siberia. The catastrophic incident forced plumes of carbon buried deep within Earth's interior up into the stratosphere, resulting in a global warming event that "led to a collapse in Earth's ozone layer. And when you thin out the ozone layer, that's when you end up with more UV-Bs," Lomax said.

In their research, the scientists also discovered a link between the burst of UV-B radiation and how it changed the chemistry of plants' tissues, leading to "a loss of insect diversity. In this case, plant tissues became less palatable to herbivores and less digestible." Because plant leaves had less nitrogen, they were not nutritious enough for the insects that ate them. That may explain why insect populations plummeted during this extinction event.

© Getty / NASA:SDO

An infrared laser beam fishes for lightning in the sky above Switzerland's Säntis mountain

TECHNOLOGY

Laser blast used to control lightning

WORDS BEN TURNER

For the first time ever, scientists have used lasers to redirect lightning towards a safe target. The experiment, which took place atop Säntis mountain on the northern edge of the Swiss Alps, is the first real-world demonstration that intense bursts of light can be used to fish for lightning from storms and redirect it to a safe location.

Scientists have previously used lasers to bend the path of electricity in the lab, but achieving this outside is challenging. After hauling their laser to Säntis' summit at an altitude of 2,500 metres, the researchers fixed it to a 124-metre-tall transmission tower there and pointed it at the sky. Then, by firing the infrared laser at passing storm clouds in short blasts of roughly 1,000 times per second, they corralled a path for lightning to hit the tower four times in six hours. The researchers said that "this is the first field result that experimentally demonstrates lightning guided by lasers".

Lightning emerges when atmospheric static electricity, generated by the friction of ice clumps and rain in storm clouds, separates electrons from atoms. The negatively charged electrons then pool at the storm clouds' bases and attract positive charges from the ground. As these electrons steadily accumulate, they begin to overcome the resistance of the air to their flow, ionising the atmosphere below them as they approach the ground in multiple forking – and invisible – 'leader' paths. When the first leader path makes contact with the ground, electrons hop to the earth from the point of contact, discharging from the bottom up in a flash of lightning, called the return stroke, that travels to the top of the cloud.

Lightning rods shield buildings by providing leader paths with a quick and safe route to discharge electrons into the ground, but the area they protect is limited by the rod's height. To get around this limitation, the scientists beamed their powerful laser bursts at the air near the rod, tearing electrons from air molecules and sweeping those molecules away to create an electron trail between a nearby storm cloud and the rod for the lightning to travel along.

Sure enough, four strikes hit the rod during the six hours of the laser's operation, easily surpassing the usual frequency of strikes on the rod of roughly 100 times per year. Even more direct evidence of the experiment's success came from one of the strikes that was captured by cameras in slow motion as it zig-zagged onto the path cleared by the rod. The scientists now want to replicate the effect in other locations with different atmospheric conditions, rods, lasers and pulses to see if this approach could be deployed more widely.

Did you know?

There are around 3 million lightning strikes on Earth every day

HISTORY

BRONZE AGE WISHING WELL DISCOVERED

WORDS JENNIFER NALEWICKI

Archaeologists in Bavaria, Germany, have unearthed a 3,000-year-old wooden wishing well overflowing with more than 100 artefacts dating to the Bronze Age. Unlike modern-day wishing wells, where people toss in coins, the items in this well were placed there for 'ritual purposes' in what is now the town of Germering. Artefacts included more than 70 well-preserved clay vessels, including numerous decorative bowls, cups and pots used for special occasions. Also found were more than two dozen bronze robe pins, a bracelet, four amber beads, two metal spirals, a mounted animal tooth and a wooden scoop. "It's extremely rare for a well to survive more than 3,000 years so well," said Jochen Haberstroh, an archaeologist with the Bavarian State Office for Monument Conservation. "Its wooden walls are completely preserved on the ground and partly still moistened by groundwater. That also explains the good condition of the finds made of organic materials."

Based on the preservation of the artefacts, researchers think villagers offered the items for cult rituals and that they were lowered into the well, as opposed to the modern-day act of tossing coins into the water. "They were intended as sacrifices for a good harvest," said Mathias Pfeil, general conservator for the Bavarian State Office for Monument Conservation.

The wooden wishing well discovered by archaeologists in Bavaria, Germany

The Brunt Ice Shelf has released another iceberg into the Weddell Sea

PLANET EARTH

Iceberg larger than London breaks off Antarctica

WORDS **TEREZA PULTAROVA**

A giant iceberg almost the size of London broke off the Brunt Ice Shelf in western Antarctica on 22 January after years of cracking. The shelf calved during the spring tide, the regular swelling of the ocean that coincides with full and new Moon. Since the iceberg broke off, multiple satellites have flown over the area, taking images of the triangular ice fragment. The British Antarctic Survey (BAS), which operates the Halley Research Station on the Brunt Ice Shelf, estimated the size of the calved iceberg to be 600 square miles. That's about the size of the London metropolitan area and a little larger than Houston, Texas.

The calving isn't related to climate change and was caused by natural processes that have been underway for more than ten years. The iceberg calved along a crack known as Chasm-1, which BAS scientists have monitored since 2012. The gradual widening of Chasm-1 prompted BAS to move the Halley Research Station 14 miles inland in 2016. The outpost has not been affected by the calving, BAS said. "Our glaciologists and operations teams have been anticipating this event," said BAS director Jane Francis.

The Moon may have nudged the new iceberg on its way as the parting happened during the so-called spring tide, the 'springing forth of the tide' that takes place around new and full Moon as a result of the Moon's small gravitational pull on our planet. In spite of the name, these phenomena have nothing to do with the season of spring.

The calving is the second such event in the past two years affecting the Brunt Ice Shelf. BAS monitors the area using an automated network of high-precision GPS sensors located around the station as well as data from Earth-observing satellites. "This calving event has been expected and is part of the natural behaviour of the Brunt Ice Shelf," said BAS glaciologist Dominic Hodgson. "It's not linked to climate change. Our science and operational teams continue to monitor the ice shelf in real time to ensure it's safe and to maintain the delivery of the science we undertake at Halley."

The 150-metre Brunt Ice Shelf is a floating sheet of ice that moves at a rate of up to 1.2 miles per year westward into the Weddell Sea. Thanks to the work of BAS, the shelf is one of the most extensively monitored ice shelves on Earth. Observations on-site and from satellites revealed in December that Chasm-1 had propagated through the entire ice shelf and that the calving was pending. BAS expects that the Antarctic Coastal Current will now carry the new iceberg away in the westward direction.

© Getty / The Bavarian State Office for Monument Protection

HISTORY

AN ANCIENT RUNESTONE MAY CONTAIN THE EARLIEST EXAMPLE OF WRITING

WORDS **JENNIFER NALEWICK**

Archaeologists have unearthed the world's oldest runestone, a squat block of sandstone with etchings scribbled across its flat surface. The ancient stone, which archaeologists unearthed in Norway, may contain the earliest example of words recorded in writing in Scandinavia. They made the find in late 2021 while excavating a gravesite in Tyrifjorden, a town west of Oslo. Radiocarbon dating of items collected at the site, including charred bones and charcoal, determined that the runestone was likely carved sometime between 1 and 250 CE.

The runestone has inscriptions containing runes, letters related to the Germanic alphabet. Eight runes on the front of the stone read 'idiberug', which researchers think could refer to a specific person or family. However, experts are still deciphering many of the etchings, as some don't appear to make any sense. "Without a doubt we will obtain valuable knowledge about the early history of runic writing," Kristel Zilmer, a runologist and professor at the Museum of Cultural History, said. The stone has been dubbed Svingerudsteinen, or the 'Svingerud Stone', after the gravesite where it was unearthed. "This find will give us a lot of knowledge about the use of runes in the early Iron Age," said Zilmer.

With inscriptions dating to 2,000 years ago, a runestone discovered in Norway could be the world's oldest

ANIMALS

Endangered Alaskan sea otters face wolf threat

WORDS **BEN TURNER**

After eradicating their deer prey, wolves on a remote Alaskan island have turned to voraciously hunting and consuming sea otters as their main food source. The discovery, made on the 20 square mile Pleasant Island located roughly 40 miles west of Juneau, Alaska, marks the very first time that sea otters (*Enhydra lutris*) have been documented as the primary food source for a land-based predator.

The wolf pack responsible for the otter carnage first swam to the island to begin hunting in 2013, subsequently causing the island's deer population to plummet. Yet after eliminating their main source of food from the island, the wolves (*Canis lupus*) didn't leave. Researchers have tracked the pack since 2015 to reveal how the wolves adapted to eat otters. "They aren't just scavenging sea otters that are dead or dying – they are stalking them and hunting them and killing them and dragging them up onto the land above the high tide line to consume them," said Gretchen Roffler, a wildlife research biologist at the Alaska Department of Fish and Game.

To study the pack's eating habits, the researchers attached GPS collars to some pack members and collected 689 samples of wolf scat – their waste – much of which was found littered along the island's shoreline. By analysing the DNA in the scat, the team could identify the wolves it came from and what they'd eaten. Between 2015 and 2020, deer dropped from being 75 per cent to just seven per cent of the pack's diet. Sea otters, on the other hand, had shot up from 25 per cent to 57 per cent of the wolves' diet across the same timeframe.

Did you know?
There are 13 otter species found across the world

The GPS collar data also confirmed that the wolves weren't leaving the island to hunt elsewhere and that when they did hunt they did so by the shore – snatching unsuspecting otters from shallow water or ambushing them as they rested on rocks during low tide. "The thing that really surprised me is that sea otters became the main prey of wolves on this island," Roffler said.

"Occasionally eating a sea otter that has washed up on the beach because it died – that is not unusual. But the fact that wolves are eating so many of them indicates it has become a widespread behaviour pattern throughout this pack, and something that they learned how to do very quickly."

A pair of northern sea otters taking a dip in Homer, Alaska

PLANET EARTH

‘Pac-Man’ microorganisms gobble down viruses

WORDS JOANNA WENDEL

Halteria is a single-celled organism covered in cilia – tiny hairs that help it move through the water

A new study finds that single-celled organisms called *Halteria* may be munching on viruses like Pac-Man eats pellets and could possibly change the way scientists think about global carbon cycling. The viruses in question belong to the *Chlorovirus* genus and are found in essentially every body of freshwater, but mostly in inland water such as lakes and ponds. Chloroviruses infect algae, stuffing the algae full of viruses until they explode. This explosion releases carbon and other nutrients into the environment that would have otherwise been eaten by the algae’s predators; instead, these nutrients are made available to other microorganisms.

This micro-recycling, while a bonus for other microorganisms, may not benefit the food chain overall. Energy generally passes upwards through the food chain as predators eat prey that have themselves consumed more simple and basic sources of nutrients, like algae. But when viruses destroy algae, that traps those nutrients at the bottom of the food chain. “That’s really just keeping carbon down in this sort of microbial soup layer, keeping grazers from taking energy up the food chain,” said John DeLong, an ecologist and associate professor of Biology at the University of Nebraska–Lincoln.

With the sheer numbers of viruses and microorganisms teeming in lakes, ponds and other bodies of freshwater, DeLong wondered if there was anything eating viruses and restoring the movement of nutrients up the food chain. He found previous research about virus-eating single-celled organisms called protists, so there was precedent for ‘virovory’ – a term that DeLong and his team coined to refer to virus-only diets. “[Viruses are] made up of really good stuff: nucleic acids, a lot of nitrogen and phosphorus,” he said, “Everything should want to eat them. So many things will eat anything they can get a hold of. Surely something would have learned how to eat these really good raw materials.”

Luckily, samples for his study weren’t hard to find. DeLong drove to a nearby pond and took some pond water back to the lab. He concentrated as many microorganisms as he could into drops of water and added a generous helping of *Chlorovirus* to some of them. What he discovered was that devoid of any other food source, *Halteria* seemed to be chomping down on viruses. The *Halteria* in a drop of water with viruses grew 15 times their original size within two days, while the number of chloroviruses plummeted. In the water drops without viruses, however, *Halteria* did not grow.

To confirm the viruses were eaten by the microscopic *Halteria*, DeLong’s team tagged the chlorovirus’ DNA with fluorescent green dye; soon enough, they spotted the glowing viruses in *Halteria*’s vacuole, a structure equivalent to its stomach. The team was thrilled, but they have more questions to answer, such as if *Halteria* eat viruses in nature or if they just gobbled up whatever snack they could find in their small drop of water. Furthermore, what does this potential diet mean for freshwater ecosystems around the globe? DeLong suspects that in a small pond, *Halteria* and other microorganisms could be eating 10 trillion viruses per day.

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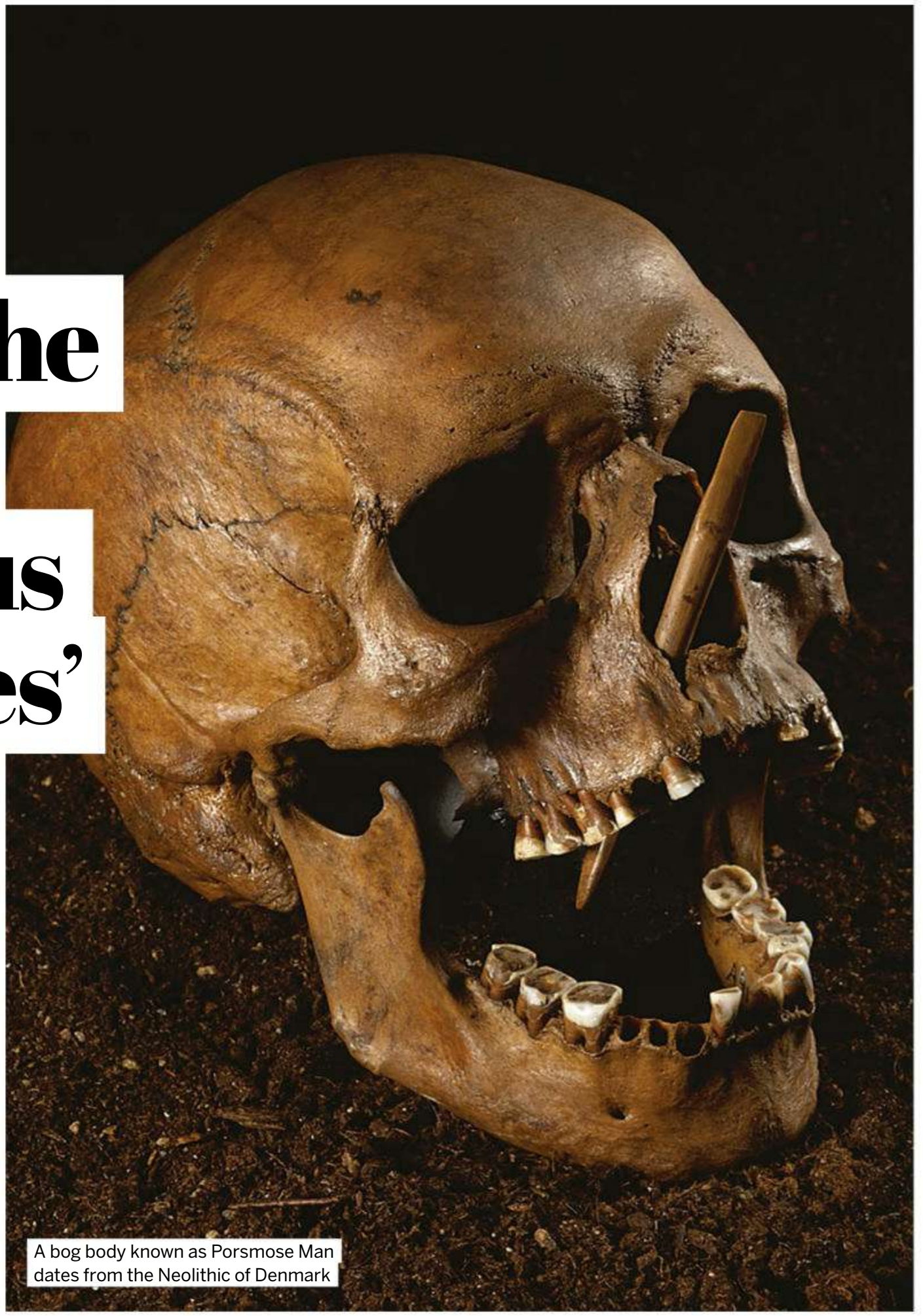
HISTORY

Scientists uncover the secrets of mysterious 'bog bodies'

WORDS **LAURA GEGGEL**



A bog body known as Porsmose Man dates from the Neolithic of Denmark

A new look at more than 1,000 bog bodies – human remains preserved in low-oxygen places with wet and spongy soils – reveals that the tradition of leaving bodies in European mires spans millennia, from the Stone Age to modern times, and that these individuals often met violent ends. However, all of these bodies didn't end up buried in bogs for the same reason. Some are likely the remains of ritualistic sacrifices, like the exquisitely preserved 2,400-year-old Tollund Man in Denmark; some are probably burials of deviants or executed criminals and others are likely the result of accidental deaths, such as drownings in these watery environments.

A few bog bodies, especially preserved mummies with skin and hair, get a lot of attention. But it would be a mistake to overlook human bones or partial human remains preserved in bogs. These bog skeletons are "actually pretty much the same as the well-preserved bog bodies that everyone knows, but they just have been preserved in a different way," in part because of the varying chemistry within bogs, said archaeologist Roy van Beek. "They provide very interesting evidence of pathology and death causes in some cases."

It's not fully understood why bogs preserve human remains so well, but the low-oxygen environment and the antibiotic properties of sphagnan, a polymer produced by *Sphagnum* moss that can lower pH and prevent spoilage, appear to play a role. To investigate bog body and skeleton trends, van Beek and his colleagues created a database of 266 sites across Northern Europe, from Ireland to the Baltic states, dating from between 9000 BCE and 1900 CE.

Often bog sites held just one deceased person, but some sites were used repeatedly over the years, with the number of preserved individuals ranging from two to about 100 per bog. In one big exception, the site of Alken Enge in Denmark is estimated to hold the remains of more than 380 people who had been killed in a violent conflict and left in open water during the early 1st century CE.

The places with the most human remains in bogs are Ireland, the UK, northern Germany, Denmark, southern Norway and southern Sweden, the team found. However, different bog hotspots emerged over time. The practice began in southern Scandinavia about 5,000 years ago during the Neolithic era and slowly spread across Northern Europe. The most recent bog bodies, from Ireland, the UK and Germany, reveal that this tradition continued through the Middle Ages and into modern times. Of the 57 people whose cause of death could be determined, 45 experienced violent deaths. In some rare cases, disease was likely the cause of death, and there were six suicide victims and four accidental deaths, such as drowning, identified from 1100 to 1900 CE, the team found.

Human remains found in bogs are "far more numerous than previously assumed," the researchers wrote in the study, noting that bog mummies spiked from 1000 BCE onward. In Europe, bogs play a unique role in preserving human remains and artefacts, providing insight into ancient peoples' practices and beliefs. "It's something that you can hardly find anywhere else in European landscapes because the preservation is so extremely good," van Beek said.

An illustration of a UAP

STRANGE NEWS

The Pentagon struggles to explain 170-plus UFO reports

WORDS **BRANDON SPECKTOR**

The US government has been inundated with hundreds of UFO encounter reports in the past year, and about half of them remain inexplicable, according to an unclassified document released by the Pentagon. The 11-page report, filed by the Office of the Director of National Intelligence (ODNI), reveals that the Pentagon has catalogued a total of 510 reports of alleged sightings of unidentified flying objects (UFOs), or unidentified aerial phenomena (UAPs) as the government prefers to call them, largely filed by US military personnel. Of these cases, 366 were newly identified in 2022, while the remaining 144 were identified in a prior ODNI report that looked at UFO data compiled between 2004 and 2017.

Of the 366 newly opened cases, 195 have been initially resolved with relatively mundane explanations; according to the report, 26 cases were identified as drones, 163 were classified as 'balloons or balloon-like entities' and six were labelled as airborne clutter, such as birds or plastic bags. These findings fit with prior claims from Pentagon officials that most recent UAP reports were likely the results of foreign surveillance drones and clutter. The remaining 171 cases are still uncharacterised and unattributed due to a lack of detailed data. Some of these cases, which involved objects moving in unusual or inexplicable ways, remain under investigation.

The report declines to mention the possibility of alien involvement in any cases. However, it does state that "no encounters with UAP [are] confirmed to contribute directly to adverse health-related effects to the observer," contrary to a litany of questionable UAP reports released in 2022 claiming that some civilians suffered radiation burns, brain damage or an 'unaccounted-for pregnancy' as a result of UFO encounters. Those reports date as far back as 1873 and were not part of the Pentagon's recent investigations.

The US government has taken a renewed interest in UFO investigations over the past several years, ever since leaked military footage of several unidentified aircraft moving in seemingly impossible ways made its way to the mainstream media. In early 2022 the Pentagon founded a new office, called the All-domain Anomaly Resolution Office, specifically to coordinate and investigate UFO reports from US military personnel.

Did you know?

The UK government's UFO desk was shut down in 2009

SPACE

A satellite spots glowing lava inside an erupting volcano

WORDS **ELIZABETH HOWELL**

Lava and smoke shine bright in a fresh satellite image of an erupting Hawaiian volcano. Kilauea has been erupting again since 5 January and its fresh activity glows in a Landsat 8 satellite image taken on 11 January. Activity extending from September 2021 to December 2022 had already created a lake of lava surrounding Kilauea. From 1983 until 2018 Kilauea had erupted almost continuously, but since 2018 eruptions are sporadic, which has created a lake of lava at Halema'uma'u crater. It appears that Kilauea and Mauna Loa have volcanic activity that influences the other caldera, even though the volcanoes don't share a connection, but that relationship isn't firmly established yet. "When Mauna Loa is frequently active, Kilauea tends to be less active, and vice versa," Jim Kauahikaua, a volcanologist with the Hawaiian Volcano Observatory, said.

Lava bursts in Halema'uma'u crater have been reaching as high as 50 metres amid the new outburst, especially after the eruption began on 5 January 2023. Landsat 8's image is a combination of natural colour and infrared wavelengths, which better highlight the heat signature of the lava. Most of the eruption during the imaging period was in the eastern part of Halema'uma'u.

An eruption of Kilauea, Hawaii's youngest and most active volcano

© Getty / Wiki: Nationalmuseet / NASA Earth Observatory image by Lauren Dauphin, using Landsat data from the U.S. Geological Survey. USGS photograph by K. Lynn

WISH LIST

The latest tech for ASTRONOMY

CANON EOS 6D MARK II

WWW.CANON.CO.UK £1,389.99 / $1,399

The Canon EOS 6D Mark II is a great DSLR for those wanting to dip their toes into astrophotography without breaking the bank. It does lack some modern features, but this is a brilliant full-frame option. Its handy vari-angle touchscreen display makes it simple to compose the scene even if the camera is pointing skyward. For astrophotographers that like a moving image, the EOS 6D Mark II can shoot 4K timelapses, making it perfect for detailed videos of the night sky, especially when paired with a slider or a star tracker. While it only captures regular video footage at full-HD 1080p, it records this at 60 frames per second for smooth results. Its dynamic range also leaves something to be desired, but if combined with plenty of calibration frames this shouldn't make much difference after image processing.

BUSHNELL LEGEND ULTRA 10X42 MONOCULAR

WWW.BUSHNELL.COM £267.71 / $199.99

The Bushnell Legend Ultra boasts exceptional optics, impressive build quality and useful extras. The magnification of 10x, coupled with a 42-millimetre objective lens, means you'll get crisp, detailed images, enhanced by Bushnell's ED Prime HD glass, multi-coated and anti-reflective optics. And all of that for less than 400 grams. Its twist-up eyecups offer great eye relief for those who wear glasses, and there's even an easy-to-grip ridge on top of the smooth external focuser where your thumb would naturally rest for added comfort. The Bushnell Legend Ultra stands out from its competition by shipping a top-quality padded case complete with a belt clip, a flip-style lens cap for the front and a rear lens cap that attaches via a lanyard to prevent it from being misplaced.

CELESTRON ASTRO FI 102

WWW.CELESTRON.COM

£379 / $529.95

Celestron's Astro Fi 102 is an excellent choice for tech-savvy beginners. After the initial set-up, which can take a little time, it's a breeze to use alongside the SkyPortal app. The app features approximately 100,000 celestial objects that you can instruct the instrument to slew to automatically. It slews quickly and quietly, and you can even use a USB video game controller to position the telescope, the familiarity of which might be attractive to gamers. To the touch this doesn't feel like a premium product, but the materials used make it a lightweight and easily portable telescope. Despite its lower price point, you'll get good views of many celestial objects, including the Moon, Saturn's rings, Mars and Jupiter, as well as Uranus and Neptune under the right weather conditions.

CELESTRON THERMOTORCH 3 ASTRO

WWW.CELESTRON.COM

£39.99 / $49.98

The ThermoTorch 3 is a night vision-preserving red flashlight that also operates as a hand warmer and low-capacity power bank. Although it has a fairly small capacity compared to other models, it has enough juice to keep your phone and other small devices charged for a night of stargazing. The hand warmer function provides up to four hours of continuous heat and can be used with the torch simultaneously. The internal battery charges within two hours, so it's ideal for last-minute adventures. There is also a white LED version of this model, so make sure you choose the Astro version for the red-light capability.

CELESTRON INSPIRE 100AZ REFRACTOR

WWW.CELESTRON.COM

£299 / $359.95

An excellent telescope for the beginner, the Celestron Inspire 100AZ is a great choice for those looking for a complete package that offers more in the way of accessories over most starter telescope bundles. The Inspire 100AZ comes with a 90-degree erect image diagonal, 10mm and 20mm eyepieces, a red LED flashlight, accessory tray, a StarPointer Pro finderscope and a smartphone adapter for basic astrophotography. Given the refractor's focal ratio, the Inspire 100AZ is limited to short-exposure photography. What's particularly impressive about the 100AZ is the overall build of its refractor; the StarPointer is a pleasant surprise since it's able to pick out faint stars under moderate light pollution for an accurate experience in hopping from one target to another.

SKY-WATCHER STAR ADVENTURER MINI

WWW.SKYWATCHER.COM £309 / $335

What is a star tracker? Based on the same technology that you'll find in a Go-To computerised telescope or in a dedicated equatorial mount for a telescope, the Sky-Watcher Star Adventurer Mini moves your camera in sync with Earth's rotation. The Sky-Watcher Star Adventurer Mini attaches to any standard tripod and rotates a DSLR camera through 360 degrees every 23 hours, 56 minutes and 4 seconds, just like our own planet. Essentially, that means you can make far longer exposures than if you just put your DSLR camera on a tripod. It's aligned using a small optical polar alignment scope, which must be done before the camera is mounted upon it.

© Amazon

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Bone-chilling -93.2°C cold
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Toxic pH 12 alkaline lake
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PIG-HUMAN HEART TRANSPLANT FIRST
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HOW IT WORKS
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YOU SWALLOW 8 A YEAR WHILE YOU SLEEP
THEY LAY EGGS UNDER YOUR SKIN
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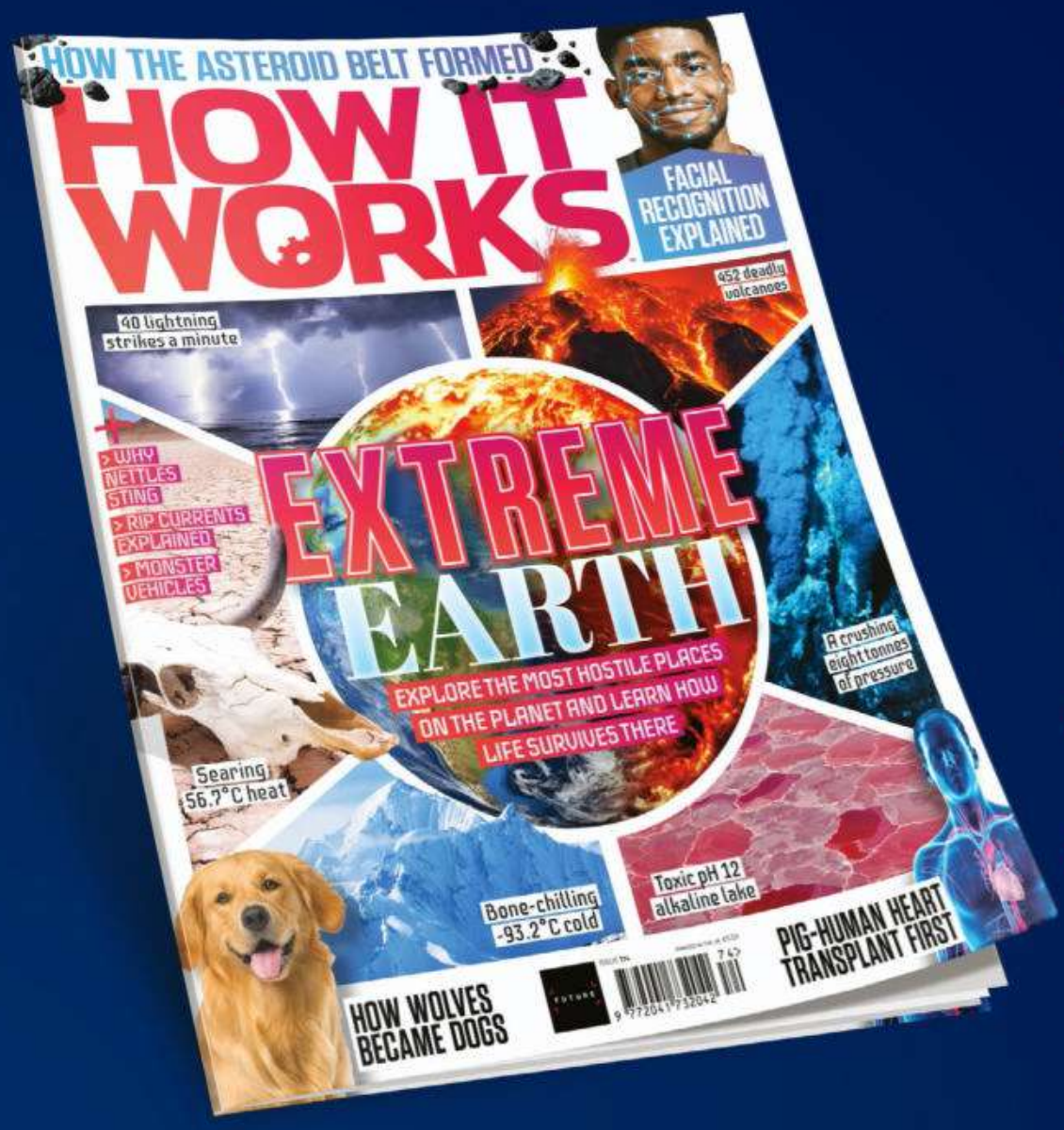
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SPECIAL

EXTREME EARTH

From natural death traps to human-made danger zones, here are some of the most hostile places on our planet

WORDS AILSA HARVEY

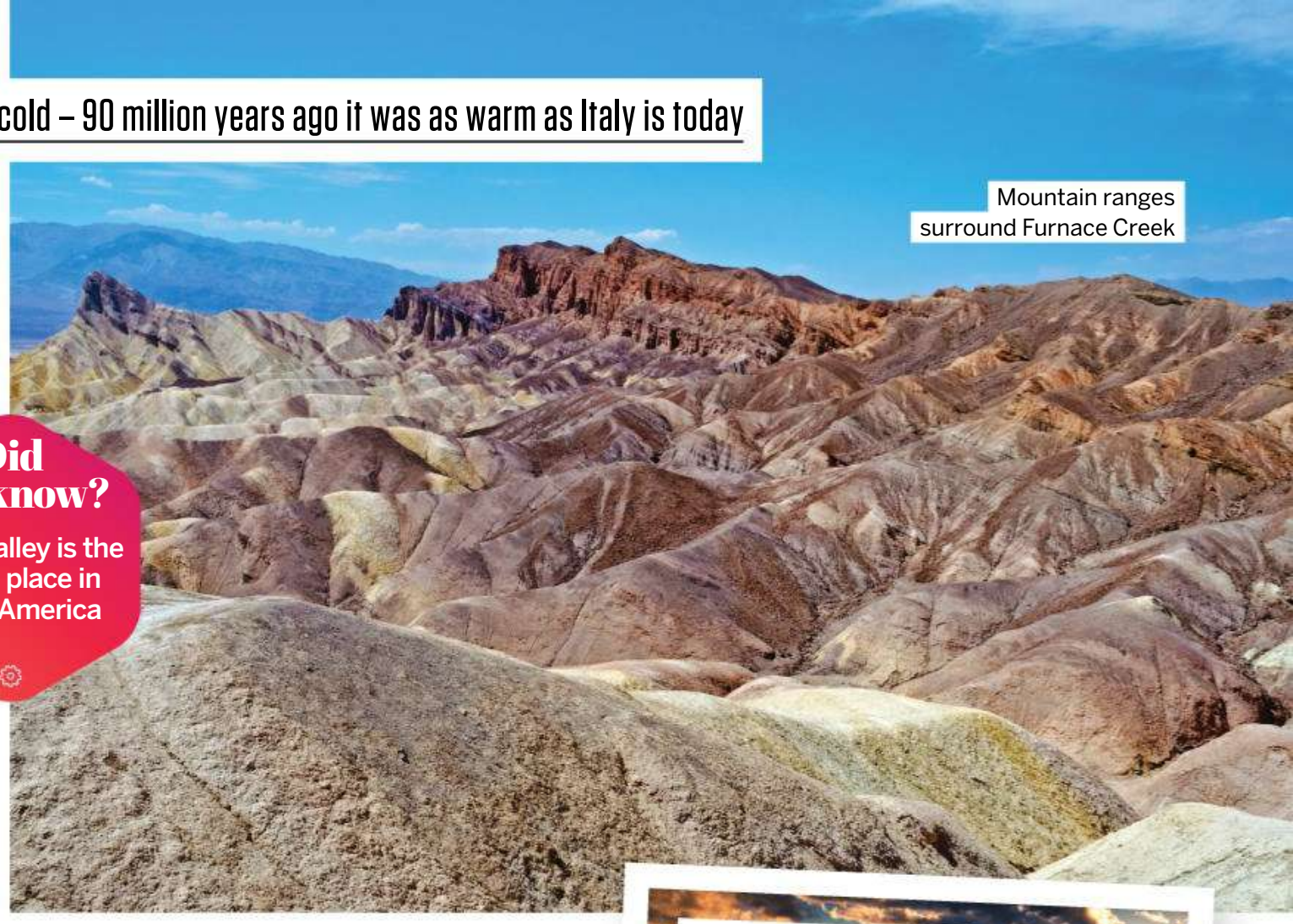
DID YOU KNOW? Antarctica hasn't always been cold – 90 million years ago it was as warm as Italy is today

WORLD'S HOTTEST PLACE

DEATH VALLEY, CALIFORNIA

Did you know?

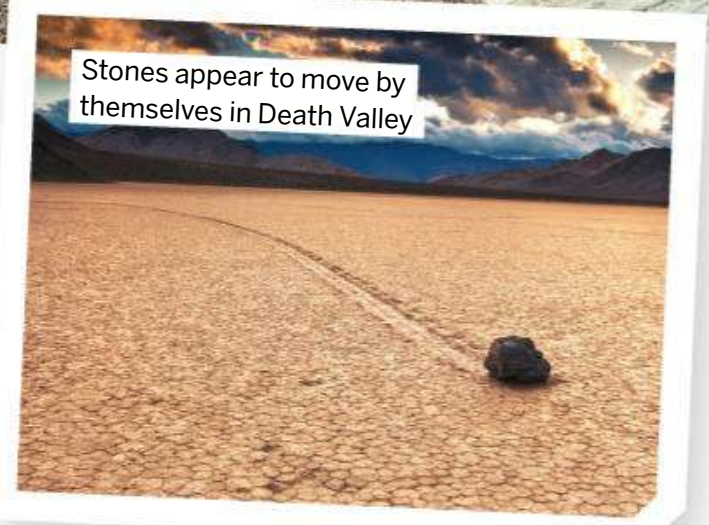
Death Valley is the lowest place in North America



Mountain ranges surround Furnace Creek

If you were to step outside on one of the hottest days in Death Valley, you wouldn't be able to feel the sweat on your skin due to its almost-instant evaporation. The tall mountain ranges that surround Death Valley – a desert valley that stretches over the border of California and Nevada – trap intense heat throughout the summer season. Here, less than five centimetres of rain falls annually, meaning the ground heats up quickly and the temperature builds between the mountains.

The valley regularly produces an air temperature of 49 degrees Celsius in shaded areas and is the site of the world's highest recorded air temperature of 57 degrees Celsius. This event took place at Furnace Creek on 10 July 1913. As Earth's changing climate produces higher temperatures, the number of days that some residents of Death Valley are forced to spend inside air-conditioned homes is increasing. Contrary to its name, there is life in Death Valley. One of the most common animals that lives there is the roadrunner. Roadrunners are small birds with high body temperatures, helping them endure the heat of the valley. Because their body temperatures are naturally 40 degrees Celsius, the intense heat doesn't impact their biology as much.

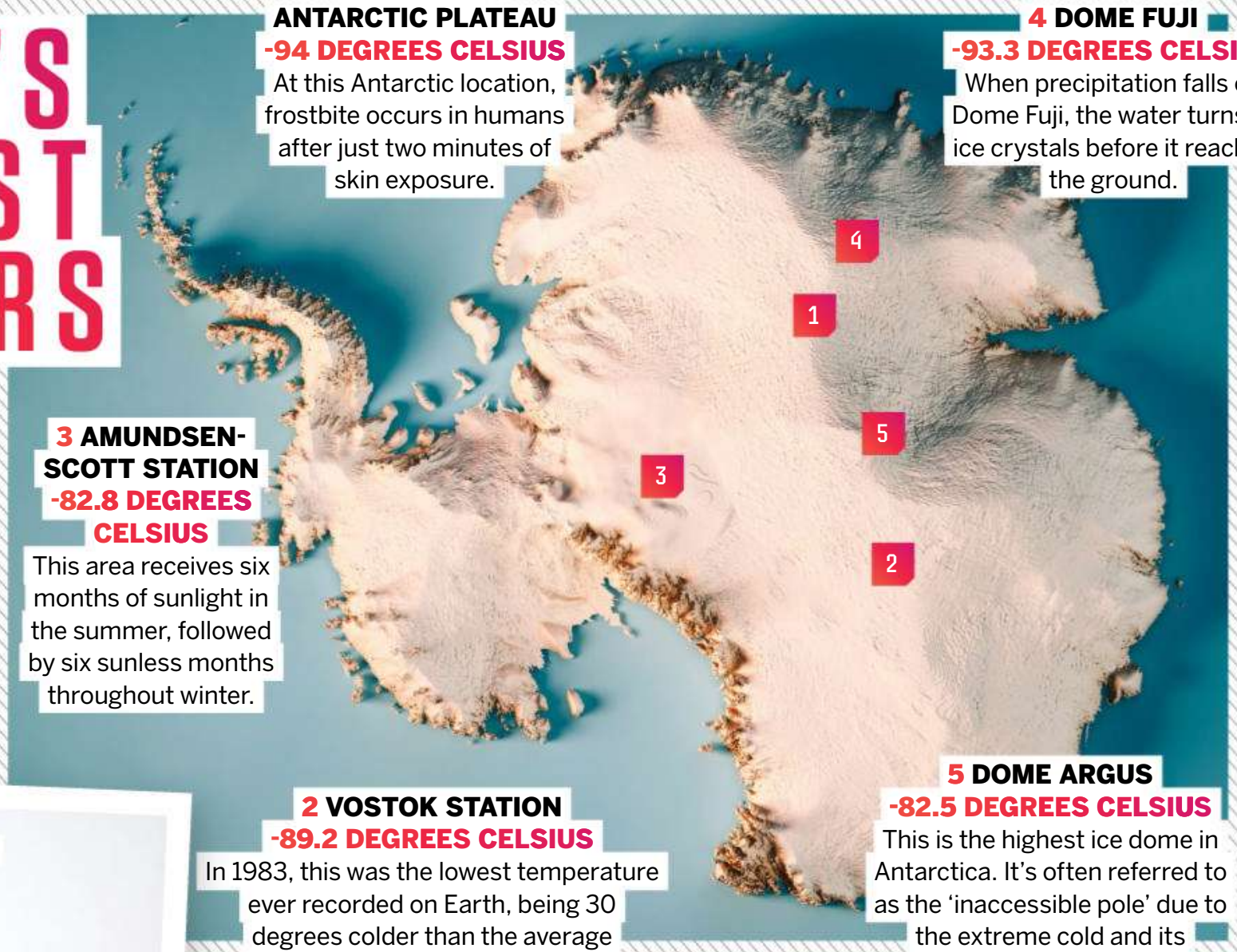


Stones appear to move by themselves in Death Valley

EARTH'S COLDEST CORNERS

ANTARCTICA

Because of the little direct sunlight hitting the icy landscapes of Antarctica, this continent is where the coldest spot in the world can be found, with temperatures low enough to freeze human skin within minutes.



1 EASTERN ANTARCTIC PLATEAU
-94 DEGREES CELSIUS
At this Antarctic location, frostbite occurs in humans after just two minutes of skin exposure.

4 DOME FUJI
-93.3 DEGREES CELSIUS
When precipitation falls on Dome Fuji, the water turns to ice crystals before it reaches the ground.

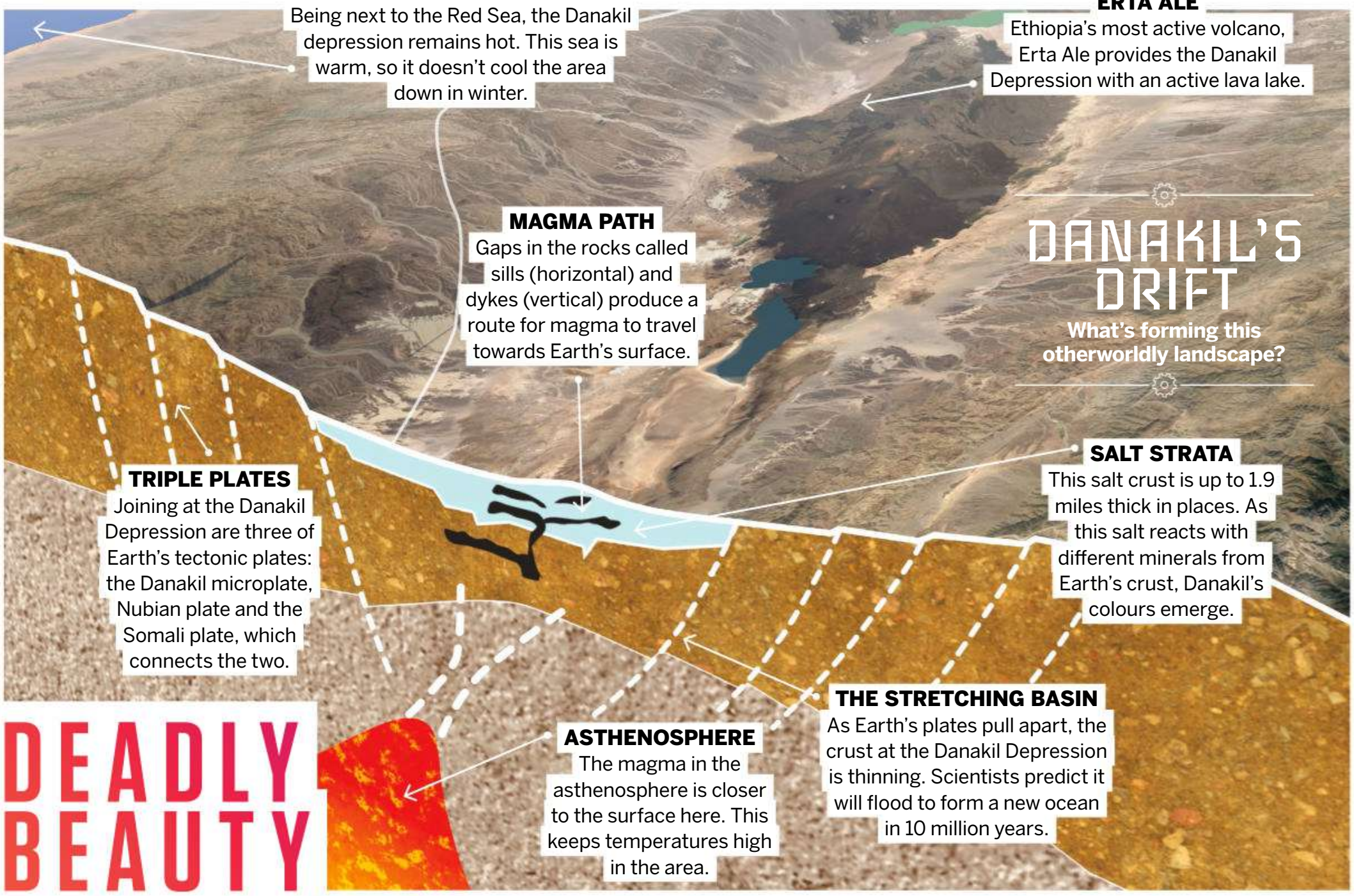
3 AMUNDSEN-SCOTT STATION
-82.8 DEGREES CELSIUS
This area receives six months of sunlight in the summer, followed by six sunless months throughout winter.

2 VOSTOK STATION
-89.2 DEGREES CELSIUS
In 1983, this was the lowest temperature ever recorded on Earth, being 30 degrees colder than the average winter in the area.

5 DOME ARGUS
-82.5 DEGREES CELSIUS
This is the highest ice dome in Antarctica. It's often referred to as the 'inaccessible pole' due to the extreme cold and its central location.

The Amundsen-Scott South Pole Station is 2,835 metres above sea level

© Alamy / Getty


RED SEA
Being next to the Red Sea, the Danakil depression remains hot. This sea is warm, so it doesn't cool the area down in winter.
ERTA ALE
Ethiopia's most active volcano, Erta Ale provides the Danakil Depression with an active lava lake.
MAGMA PATH
Gaps in the rocks called sills (horizontal) and dykes (vertical) produce a route for magma to travel towards Earth's surface.
TRIPLE PLATES
Joining at the Danakil Depression are three of Earth's tectonic plates: the Danakil microplate, Nubian plate and the Somali plate, which connects the two.
SALT STRATA
This salt crust is up to 1.9 miles thick in places. As this salt reacts with different minerals from Earth's crust, Danakil's colours emerge.
THE STRETCHING BASIN
As Earth's plates pull apart, the crust at the Danakil Depression is thinning. Scientists predict it will flood to form a new ocean in 10 million years.
ASTHENOSPHERE
The magma in the asthenosphere is closer to the surface here. This keeps temperatures high in the area.

DANAKIL'S DRIFT

What's forming this otherworldly landscape?

DEADLY BEAUTY

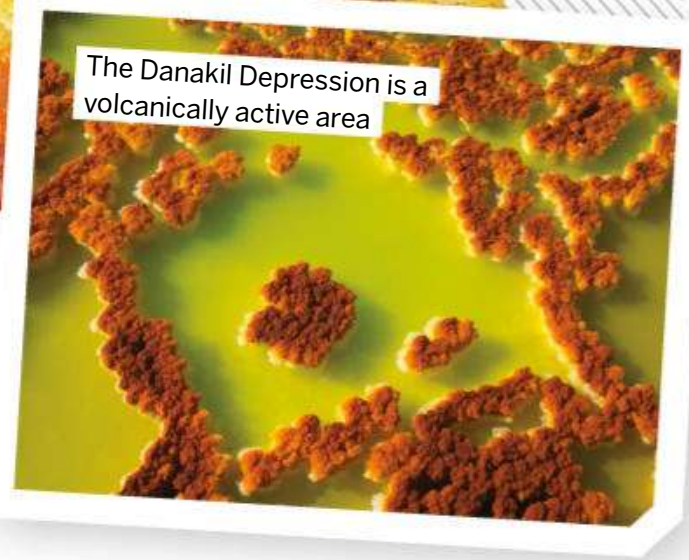
THE DANAKIL DEPRESSION, AFAR, ETHIOPIA

The vibrant landscape of the Danakil Depression looks like a painting created by an abstract artist. The Sun highlights the fluorescent spatterings that decorate red-tinged rocks as they protrude from the still green waters. However, this place is as deadly as it is mesmerising. At 125 metres below sea level, the area has high hydrothermal activity and an impressive collection of Earth's overflowing elements, and it's these that produce its rainbow appearance.

The reddened rocks are a result of high volumes of iron oxide, the yellow deposits are a range of sulphates, while copper sulphates are the cause of the blue-green water. Above these steamy springs, plumes of chlorine and sulphur vapour produce a toxic fog, while the waters are heated to temperatures near boiling.

Despite the volatile cocktail of chemicals in one of the world's hottest and driest patches, some extremophiles – organisms that live in environments that are usually hostile to life – can be found in the Danakil Depression. But what can survive in a land where exceptionally salty pools are more acidic than battery acid?

These acidic springs look like the surface of another planet


The Danakil Depression is a volcanically active area

Two types of bacteria have been found here, one of which lives in the salt springs and another in the nearby lakes. The bacteria are categorised as polyextremophiles as they are adapted to life in an environment that is hostile to life in a number of ways.

DID YOU KNOW? Animals in Chernobyl have high levels of radioactive caesium-137 in their bodies

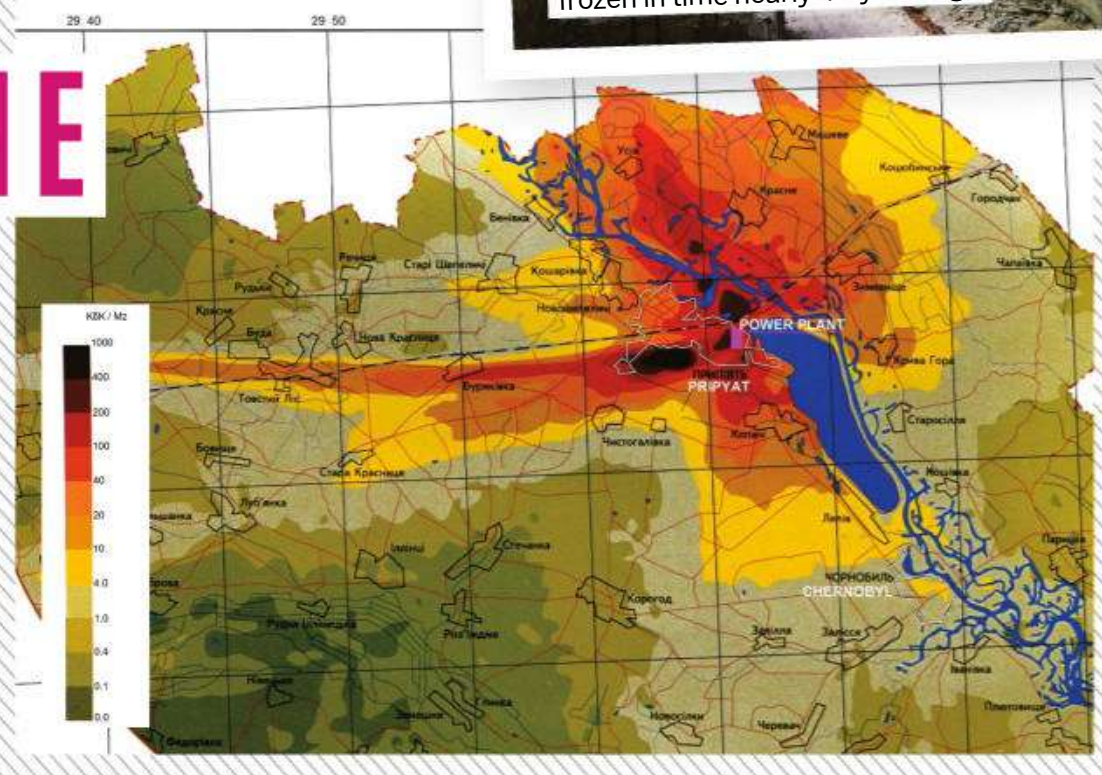
RADIOACTIVE EXCLUSION ZONE

Abandoned buildings in Pripyat, frozen in time nearly 40 years ago

PRIPYAT, UKRAINE

When the Chernobyl Nuclear Power Plant went into meltdown on 26 April 1986, the immediate radioactive fallout could kill an exposed person in just over a minute. It was the world's worst nuclear disaster, and the scale meant that the detriment to life couldn't be hidden. In fact, radioactive clouds could be seen from as far away as Sweden. After trying to hide the extent of the disaster from the world, the Soviet Union eventually plotted an official 'exclusion zone', evacuating everyone in the area due to the deadly radiation levels. This zone has an 18-mile radius, including the nearby city of Pripyat, which became a ghost town overnight as the entire population of 49,000 people was evacuated.

While radioactive levels are naturally diminishing, the area still has multiple dangerous 'hotspots'. Security guards who restrict access to these hotspots can only work for 15 days before spending the following 15 days away from the area to recover from radiation exposure. High radiation levels will remain in the exclusion zone for 300 years, but animals and plants have since moved into the places that humans no longer inhabit.



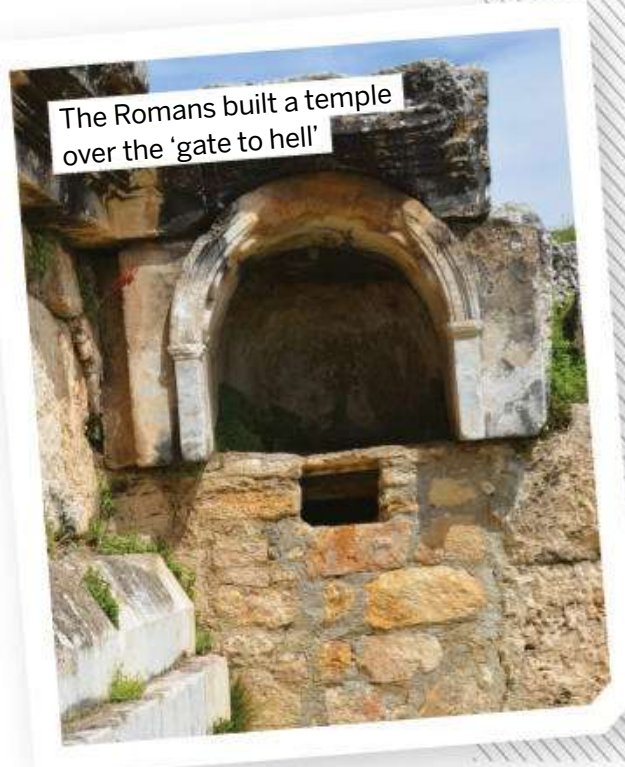
This colour-coded map shows the density of plutonium contamination in the power plant's surrounding areas. This ranges from the highest contamination (black) to relatively low contamination (green)

ROMAN 'GATE TO HELL'

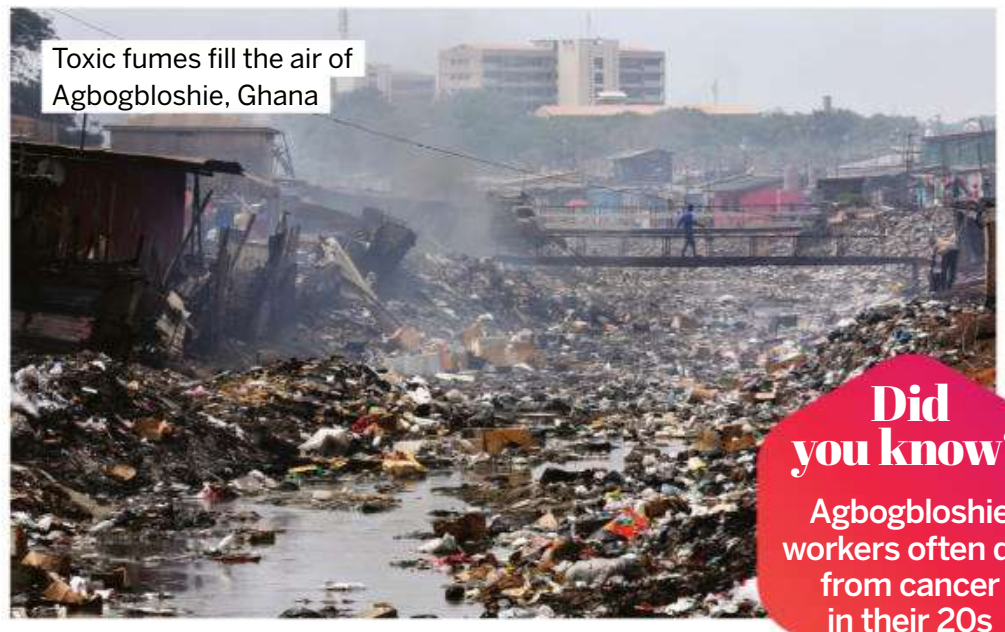
PAMUKKALE, DENIZLI, TURKEY

2,000 years ago in the ancient city of Hierapolis, Romans were drawn to a cave that caused everything from small birds to large mammals to drop dead when they approached its entrance. The science behind this deadly cave was unknown at the time, and so ancient Romans believed the cave released the 'breath of death' from the god of the underworld. This led to a temple being built over the cave, attracting frequent visits to the spectacle.

In reality, scientists have now discovered that deep below this cave is a crack in Earth's crust, releasing toxic concentrations of carbon dioxide gas through the cave's narrow opening. At the opening of the cave, carbon dioxide levels are between 4 and 53 per cent, up to 91 per cent at deeper points inside the cave. Concentrations of just over seven per cent of this gas can render a person unconscious and kill them due to a lack of oxygen.



The Romans built a temple over the 'gate to hell'



Toxic fumes fill the air of Agbogbloshie, Ghana

Did you know?

Agbogbloshie workers often die from cancer in their 20s

TOXIC E-WASTE DUMP

AGBOGBLOSHIE, ACCRA, GHANA

This Ghanaian wetland used to be a lush land that served as a fresh water supply, an open area for cattle to graze and home to one of the largest food markets in Accra. However, ships have been sailing to illegally dump electronic waste here since 2000, leading to the soil, water and air becoming gravely contaminated by toxic heavy metals and chemicals. From discarded electronic equipment, metals such as beryllium, mercury and cadmium leach into the environment.

Some locals use the dump as a workplace to dismantle and burn electronics to extract valuable metals to sell. This highly dangerous job has devastating health implications. Similarly, those living in Agbogbloshie have no choice but to use the toxic environment for producing food – but the products can be just as deadly. One free-range egg that was hatched by an Agbogbloshie chicken exceeded the European Food Safety Authority's maximum chlorinated dioxin levels by 220 times. This deadly compound can cause cancer and damage the immune system, and it's just one of over 1,000 harmful substances killing residents of Agbogbloshie.

© Alamy / Getty / Science Photo Library / Carole Raddato/ Wikimedia Commons / Illustration by Adrian Mann

Around 50 volcanic eruptions take place annually around the world

RING OF FIRE

PACIFIC COAST

Tectonic plates are a giant jigsaw covering the surface of our planet. These 17 major pieces of Earth's crust appear to fit together neatly on a map. However, they don't fit as perfectly in reality as the huge slabs are constantly moving, often causing friction between two adjacent plates. When two plates collide, pull apart or slide past each other, earthquakes and erupting volcanoes can result. Two jolting plates can send rippling vibrations across 60 miles of land, while two separating plates can create a route for magma to leak above ground. The Ring of Fire is the name given to a border of the Pacific Ocean that surrounds several tectonic plates. The movement of these plates means that most of the world's earthquakes and volcanic eruptions occur somewhere along this volatile path. In total, 452 volcanoes lie on the Ring of Fire – 75 per cent of the world's volcanoes. Meanwhile, 90 per cent of all earthquakes occur in this region.

DISASTER HOTSPOTS

These are some of the Ring of Fire's biggest natural disasters

6 INDIAN OCEAN EARTHQUAKE
An underwater earthquake occurred here on 26 December 2004. The result was a tsunami that travelled across the water for seven hours. It reached many South and Southeast Asian coasts and reached as far as East Africa.

5 GREAT ALASKAN EARTHQUAKE
On 27 March 1964, a magnitude 9.2 earthquake was triggered in this area of the Ring of Fire. This event permanently raised some areas of the coastline by nine metres.

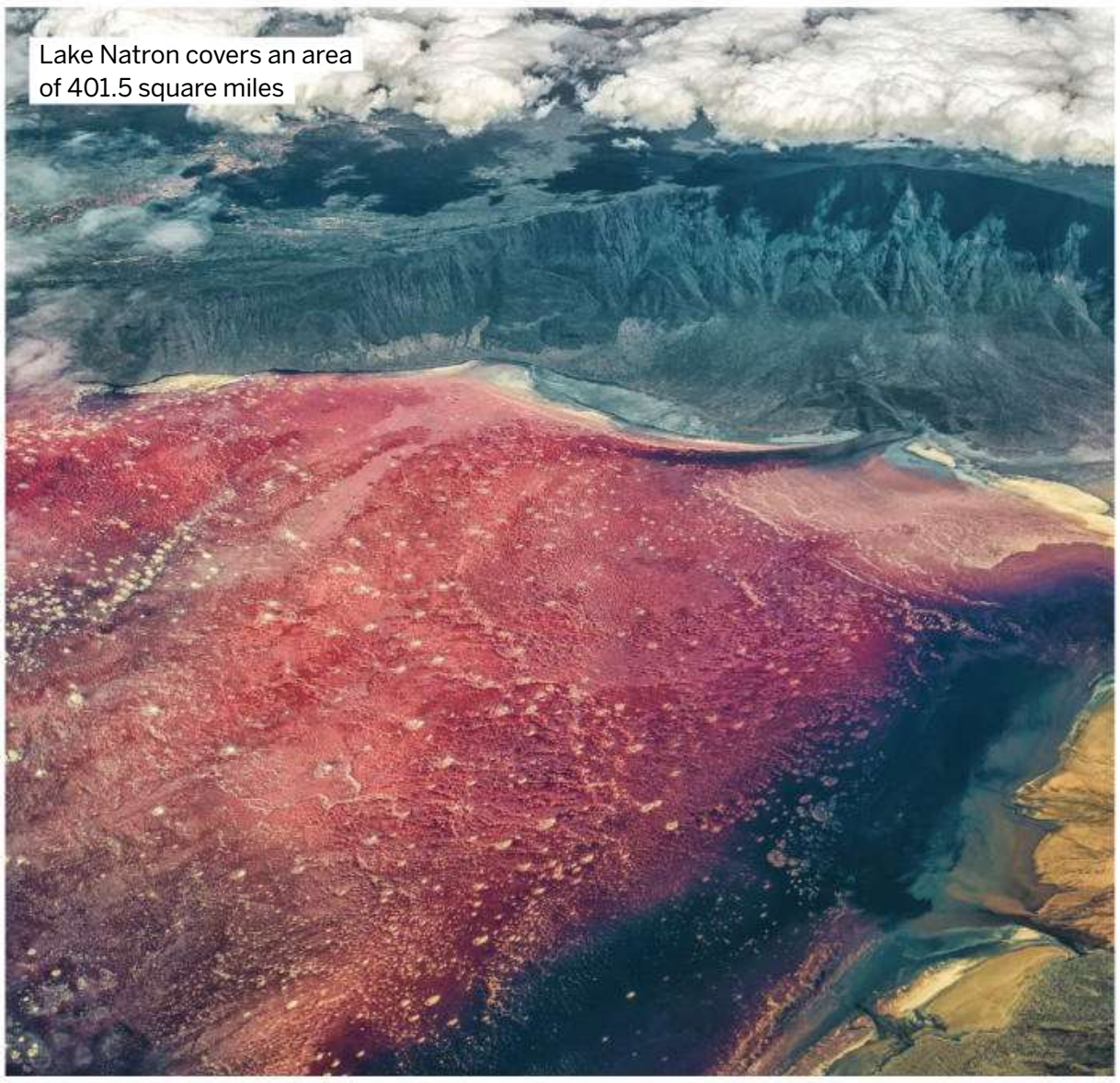
3 MOUNT RUIZ
In 1985, this Colombian volcano erupted twice, causing two mudslides. These events buried the nearby towns of Armero and Chinchiná.

2 KRAKATOA
Since its 1883 eruption, which triggered 37-metre tsunamis and killed 36,000 people, Krakatoa has regrown to 460 metres. Scientists predict it is due another large eruption in the near future.

1 MOUNT TAMBORA
This active volcano was responsible for 80,000 deaths when it erupted in 1815. This was the deadliest volcanic eruption in history.

4 VALDIVIA
The largest earthquake in the 20th century occurred in 1960. The magnitude 9.5 earthquake caused devastation in Chilean cities.

DID YOU KNOW? More active volcanoes are located on the west side of the Ring of Fire


Lake Natron covers an area of 401.5 square miles

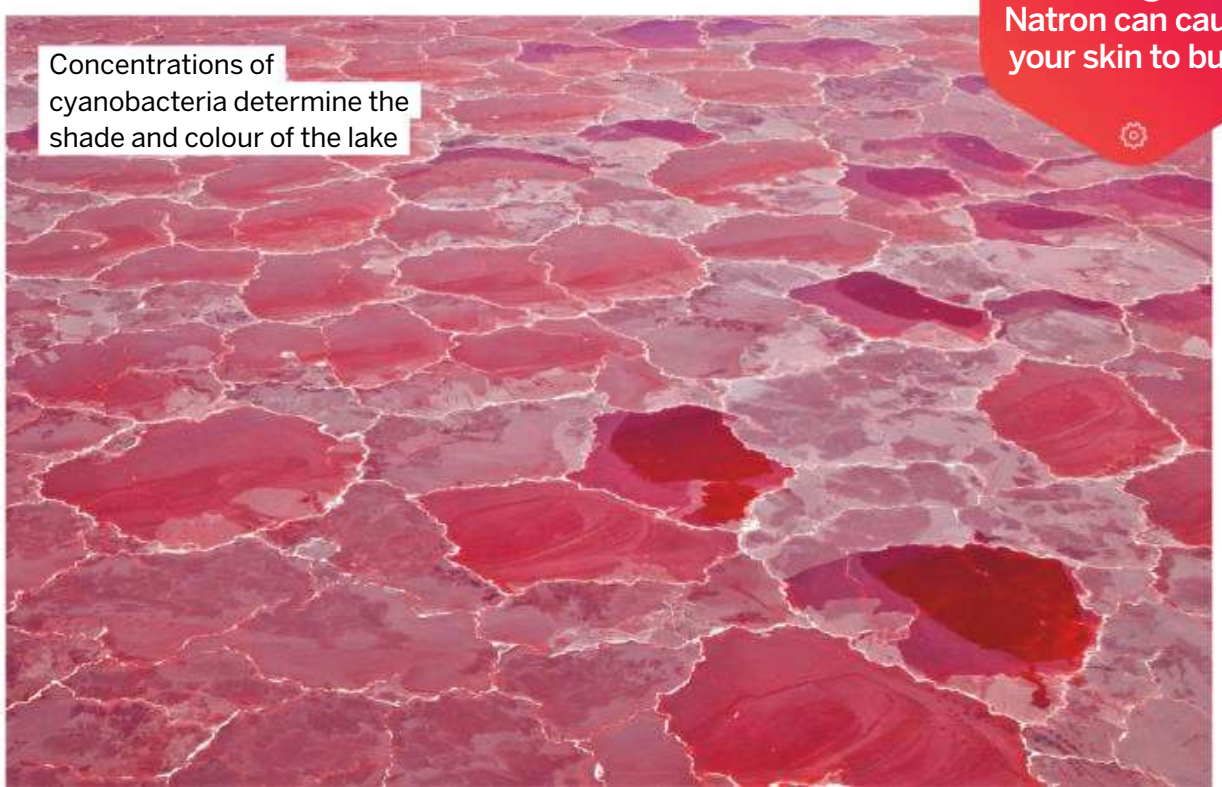
DEADLY RED LAKE

LAKE NATRON, NGORONGORO, TANZANIA

Occasionally littered with calcified corpses, this bright-red body of water gives a clear warning to any life that approaches its shores. While the majority of this lake belongs to Tanzania, the very tip crosses the border into Kenya. At the opposite end lies its source – Mount Ol Doinyo Lengai. This volcano releases runoff water from its slopes, mixing it with volcanic material. As a result, the lake's water becomes highly salty and alkaline. The high salt concentration limits the animals and plant life that can survive in the waters. However, one organism that thrives in its salty waters is the extremophile cyanobacteria. This is a red algae that colours the lake and makes it toxic to other life. When consumed, cyanobacteria attack the cells, nervous systems and organs of animals and humans. And if an animal dies in these waters, there's a high chance that it will become calcified as the salty lake hardens its body.

Did you know?

Touching Lake Natron can cause your skin to burn


Concentrations of cyanobacteria determine the shade and colour of the lake

5 MOST EXTREME WEATHER LOCATIONS

1 STORMIEST
Lake Maracaibo in Venezuela experiences around 1.2 million lightning strikes every year. These strikes occur 28 times a minute and can last for nine hours at a time. Out of a year's 365 days, lightning will hit this lake on 300 of them.

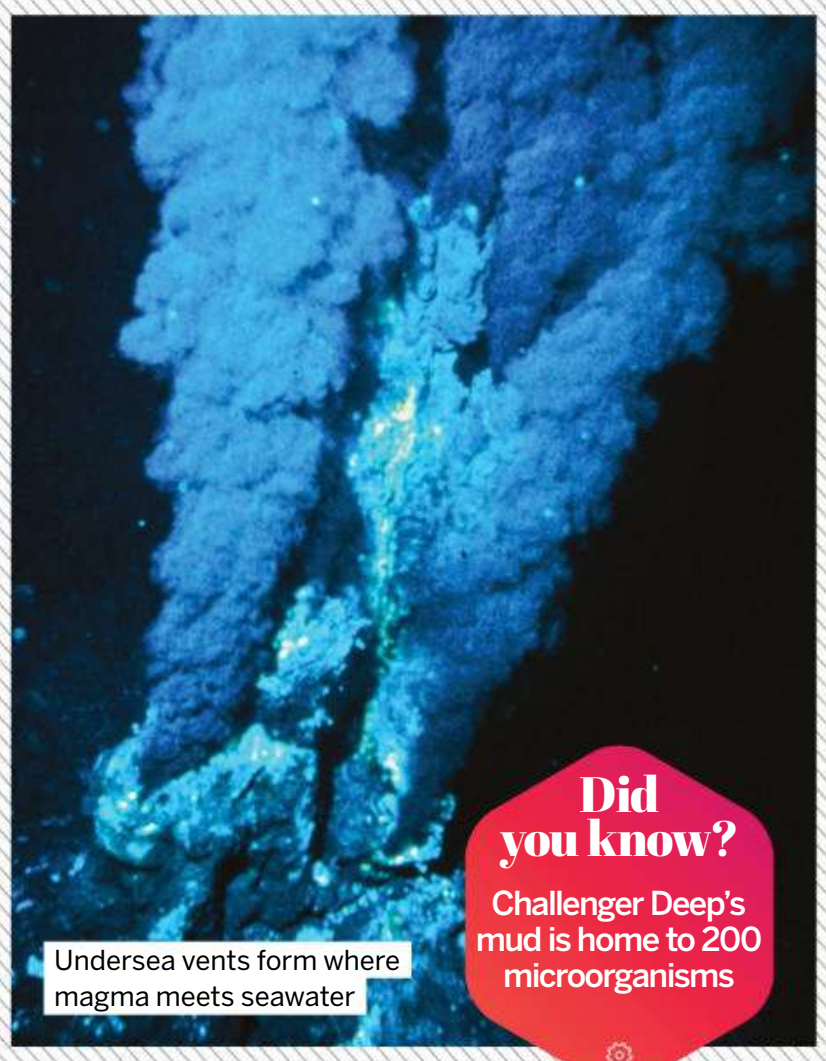
2 WINDIEST
With regular wind speeds of 150 miles per hour, Commonwealth Bay in Antarctica is regarded as the windiest place on Earth. This is due to its crescent shape, which forces wind through the bay.

3 WETTEST
The village of Māwsynram is the rainiest place to live on Earth. Situated in northeastern India, the residents are used to an annual rainfall of around 12,000 millimetres. Homes regularly suffer battered roofs and landslides are a common threat.

4 DUSTIEST
The Bodélé Depression in Chad is the largest single source of dust on Earth. The strong surface-level winds blow small mineral particles into the air. More than half of the minerals that fertilise Amazon soil were blown from Bodele.

5 DRIEST
In stark contrast to Māwsynram, the Atacama Desert in Chile receives less than one millimetre of rain annually. In some areas of the desert there has been no rain for 500 years.

© Alamy / Getty



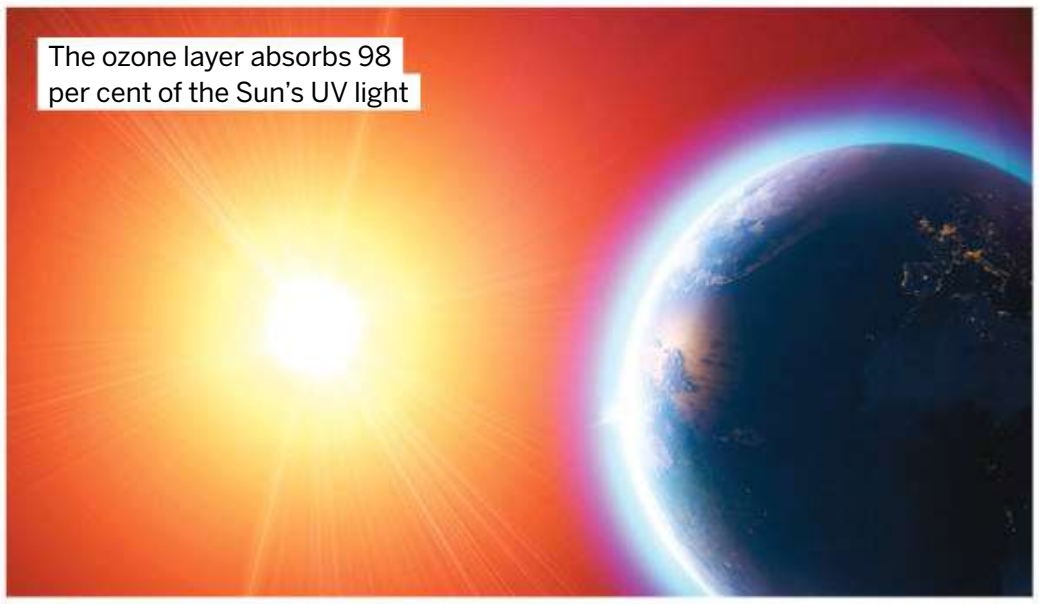
CRUSHING OCEAN DEPTHS

The light-producing organs on a hatchetfish's belly are called photophores

CHALLENGER DEEP, MARIANA TRENCH, PACIFIC OCEAN

The deepest point in the ocean is 10,929 metres underwater. It's called the Challenger Deep and is located at the bottom of the Mariana Trench. At these depths, most life forms fail to survive. The trench is devoid of natural light and has a water pressure 1,000 times that experienced at sea level.

Although life is limited, some creatures do call this isolated chasm their home – and these creatures are nothing like those near the surface. To combat the pressure, fish such as the Mariana snailfish have a gap in their skulls. This is because a fully formed skull would crack under the extreme pressures of the deep. Another trench-dweller is the deep-sea hatchetfish. These fish have light-producing organs lining their bellies to help them see in the total darkness. Amphipods, which are shrimp-like crustaceans, also inhabit the deepest parts of the Mariana Trench, such as *Hirondellea gigas*.


The ozone layer absorbs 98 per cent of the Sun's UV light

BEYOND THE OZONE
EARTH'S UPPER ATMOSPHERE

Earth ends and space begins in the exosphere. This is the final layer of Earth's atmosphere, between 3,700 and 6,200 miles from Earth's surface. Despite being part of Earth's atmosphere, the conditions are too harsh for most life forms to survive. Instead, most exist below the ozone layer – a section of the stratosphere around 9.3 to 18.6 miles above Earth's surface, largely composed of ozone molecules. These molecules are made of three oxygen atoms, forming a layer of gas that surrounds the planet and protects life by absorbing the high levels of ultraviolet (UV) radiation emitted by the Sun.

Some microorganisms may be living over 30 miles above Earth in the stratopause layer of the atmosphere. Organisms could have reached these heights by riding storms or the upthrust from a volcanic eruption. Having been elevated past the protective ozone layer into layers of intense radiation, only UV-resistant strains of organisms, such as the bacterial species *Micrococcus luteus*, have the potential to survive.

ACIDIC IRON MOUNTAIN
REDDING, CALIFORNIA

The world's most acidic water isn't a result of natural processes, but human activity. In this case, the cause is mining. Iron Mountain is a site with ten different mines that were in operation for nearly a century between 1879 and 1963. This incessant work provided a path for some of the mined metals to contaminate the surrounding waterways. In one of the copper and zinc mines, extremely acidic water was discovered. Dripping from the stalactites, this water, with a pH of -0.7, seeped through the mine and entered rivers. Water with this level of acidity is strong enough to kill most aquatic life within several miles of the entry point.

Iron drained from mines can produce red, yellow or orange sediment in rivers

DID YOU KNOW? In the past Boiling Lake has cooled, its water levels have changed and it has temporarily dried up

THE BOILING LAKE

BOILING LAKE, DOMINICA

After the four-hour hike needed to reach this lake from the nearby village of Laudat, you may be tempted to take a refreshing swim in its waters. However, this could result in serious injury or death, because this lake can turn into a deadly cauldron without warning. Boiling Lake, as its name implies, can begin to naturally boil as its water is heated by hot gas released from deep underground. The lake is classified as a fumarole – a vent in Earth's surface – that releases volcanic gases. This makes the water acidic and grey-blue in colour. There's usually an eerie cloud surrounding Boiling Lake, which you are likely to see before arriving at the vent. Due to the unpredictability of this boiling natural wonder, its depth has never been measured. When boiling, the edges of the water have been measured at 91.5 degrees Celsius, but the exact temperature at its centre remains unknown.

1 MOLTEN LAVA
The lava at the base of the vent heats any surrounding water in the rock.

2 TRAPPED WATER
Once water has seeped down through the porous rock and is trapped close to the lava, its temperature rises.

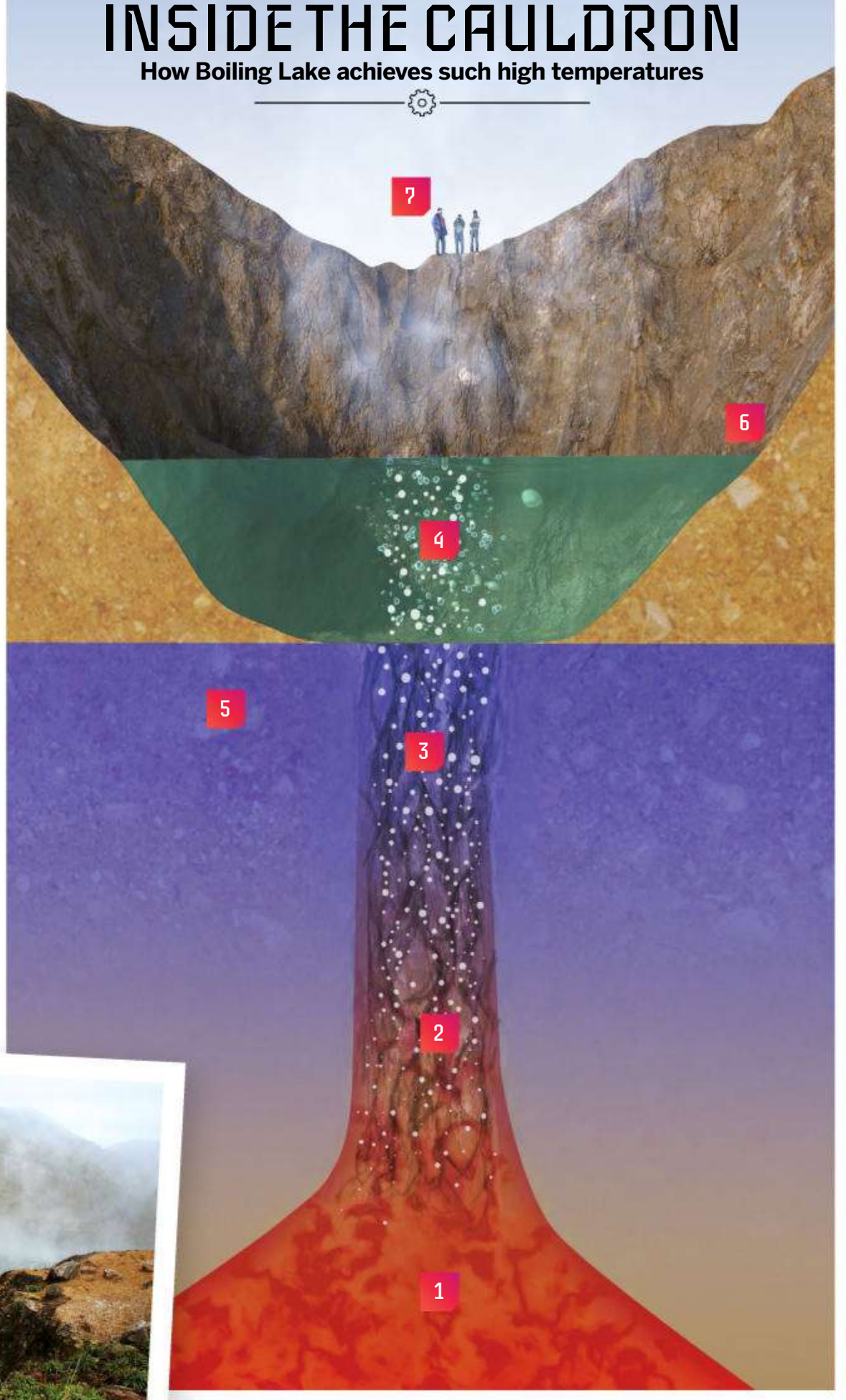
3 PERMEABLE LAYERS
After the trapped water has been heated to boiling point, it bubbles up towards the lake through the many gaps in the rock.

4 BUBBLING UP
Bubbles form mostly at the centre of the lake, where the volcanic gases are released.

5 LAKE SIDES
The rock surrounding the lake mostly consists of clay, pumice and stone and has low permeability.

6 REFILLING STREAMS
Two small streams run into the boiling lake.

7 VISITOR PLATFORM
It's important to stay away from the edge of the lake. Depending on the conditions, the water level can drastically change.



Boiling Lake is surrounded by steep rocky sides

5 DEADLY ISLANDS

1 SNAKE ISLAND, BRAZIL
The golden lancehead viper exists only on this small, unpopulated island. With one bite from this snake, there's a seven per cent chance of death.

2 BIKINI ATOLL, MARSHALL ISLANDS
Between 1946 and 1958, this island was used to test the United State's nuclear weapons. Bikini Atoll is still scattered with radioactive material, and it's deemed unsafe for Bikinians to return.

3 MIYAKE-JIMA ISLAND, JAPAN
This island is largely dominated by the volcano Mount Oyama, which erupted in the year 2000. Because the volcano can release harmful sulphuric gas at any time, those who live on Miyake-jima Island carry gas masks everywhere.

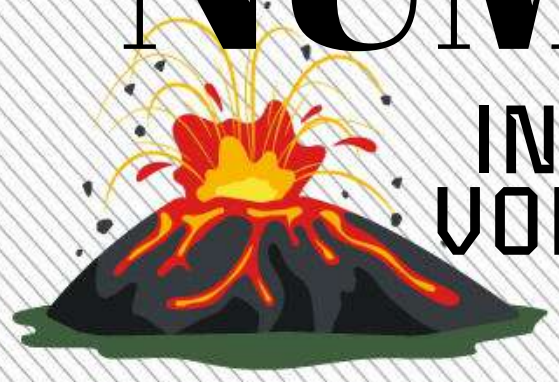
4 GRUINARD ISLAND, SCOTLAND
In 1942, bombs filled with anthrax were detonated on the island as part of a germ warfare experiment. Anthrax is a lethal disease, so the island is now uninhabited.

5 RAMREE ISLAND, MYANMAR
Saltwater crocodiles are the largest reptilian predators on Earth, and on Ramree island there are thousands of them. During World War II, around 500 of 1,000 Japanese troops were killed by the island's crocodiles.

© Alamy / Getty / Illustration by Adrian Mann

SPECIAL

EXTREME NUMBERS



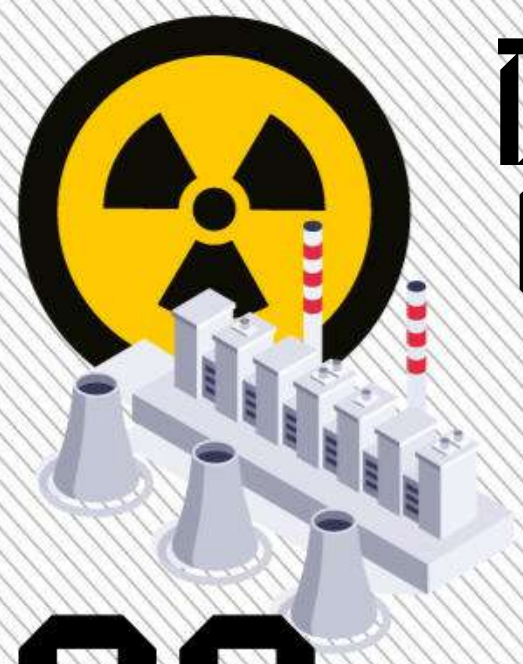
INDONESIA HAS MORE VOLCANOES THAN ANY OTHER COUNTRY

FOUR DEGREES CELSIUS

By 2100, global average temperatures may be significantly warmer

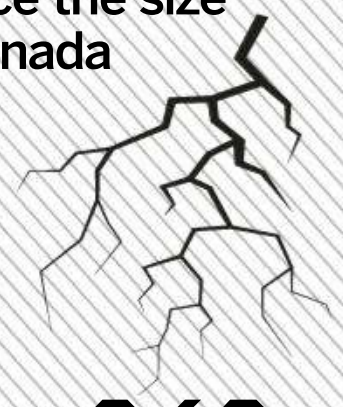
3,373,000 ACRES

Death Valley is twice the size of Ottawa, Canada



24,800 MILES

The length of the Ring of Fire is about the same as Earth's circumference



248 MILES

You can see Lake Maracaibo's lightning from afar

20%

One-fifth of the emergency workers at Chernobyl lost their lives to radiation exposure after attempting to extinguish the fires

THE WIND AT COMMONWEALTH BAY IS STRONGER THAN 'GALE FORCE' ON THE BEAUFORT SCALE

28,000

Air pollution kills a high number of people every year in Ghana

In 250 million years, the land in the Ring of Fire may merge into a supercontinent

22 people have descended to the Challenger Deep

SARNO RIVER IS THE MOST POLLUTED RIVER IN EUROPE

THE WIND IN THE DANAKIL DEPRESSION CAN MAKE YOUR SKIN FEEL LIKE IT'S BURNING

40 MILLION YEARS

The Antarctic ice sheet has existed since the Eocene epoch

2 BILLION YEARS

Oxygen was absent from the atmosphere for nearly half the age of Earth

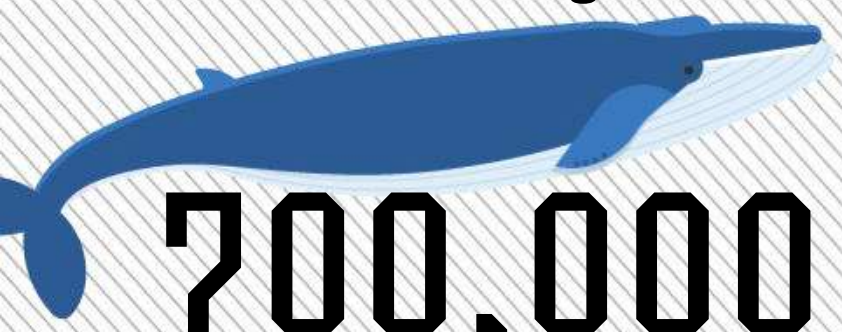
3,600

The number of people evacuated from Miyake-jima Island in 2000 due to toxic gas

IT'S LIKELY THAT THE ATACAMA DESERT HAD NO SIGNIFICANT RAINFALL BETWEEN 1570 AND 1971

TEN PER CENT

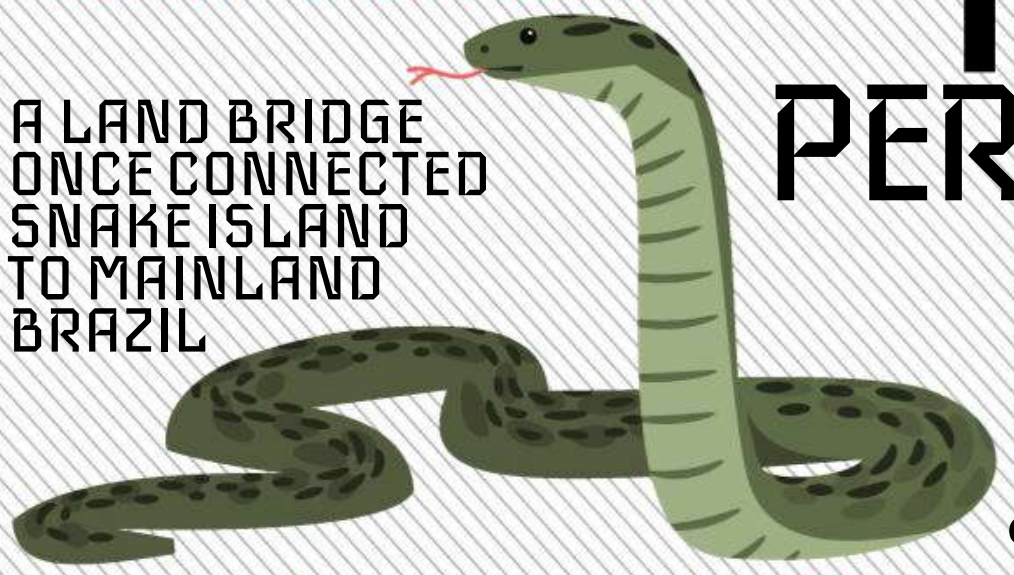
One-tenth of Mawsynram's average annual rainfall fell within 24 hours on 16 June 2022



700,000 TONNES

The average daily dust that lifts from the Bodélé Depression is equal to the weight of 6,000 blue whales

A LAND BRIDGE ONCE CONNECTED SNAKE ISLAND TO MAINLAND BRAZIL



Antarctica is technically a desert

© Getty

HOW WOLVES BECAME DOGS

Our canine companions have changed physically and mentally over millennia

WORDS **SCOTT DUTFIELD**

Humans and dogs have sat side by side for thousands of years, but how did the two come together? Between 27,000 and 40,000 years ago, dogs (*Canis lupus familiaris*) and modern-day grey wolves (*Canis lupus*) broke away from an unknown extinct wolf species. While the grey wolf remained in the wild, dogs found themselves by humans. The first fossil evidence of our canine bond was found in Germany in 1910 and dates back 14,200 years. The remains had been buried in a grave alongside human companions – an adult man and a woman. It remains unclear exactly when and where dogs were first domesticated, but it occurred before the development of agriculture, while humans were still hunter-gatherers.

The theory of how prehistoric dogs became domesticated is through a process known as the commensal pathway, whereby wolves were drawn to human settlements by things that are attractive to a wild animal, such as discarded food. During the time humans began running with wolves in northern Eurasia, the land was largely covered in ice. Their main food source at the time was protein-packed lean meat from other prehistoric animals. Although humans benefit from consuming high-protein sources, we need a varied diet to survive.

Did you know?

The largest reported wolf pack had 400 members

Wolves, on the other hand, don't require a varied diet and can survive solely on protein-rich foods. It's been proposed that humans may have shared food with less aggressive and more sociable wolves and driven away aggressive wolves, thus beginning the process of domestication. Along with benefiting from the spoils of human hunters, over time wolves likely played a role in protecting the territories shared by wolves and humans, possibly even working together to hunt for food. Humans may also have reared orphaned wolf pups or even taken them from their dens. Using pre-chewed food and breast milk, wolf pups may have formed social bonds with humans from a young age, leading to their domestication.

PUPPY-DOG EYES

Humans have transformed the muscle anatomy of dogs' faces. Researchers compared the muscular anatomy of dogs and wolves, discovering a muscle called the levator anguli oculi medialis uniformly among dogs, but not in wolves. This muscle is responsible for prominently raising a dog's inner eyebrow, which the researchers suggest resembles the expression humans make when they express sadness or 'puppy-dog eyes'. This relatable ability may have triggered a nurturing response in people, and therefore may have been a trait that humans selected for during breeding.

Domestication has created muscles in dogs' faces that make them look sad

1 MISSING DEWCLAW

Wolves have much larger paws than dogs, but they lack a vestigial first toe on their hind legs.

DID YOU KNOW? A wolf's howl can reach up to 115 decibels. In comparison, a lawn mower is around 107 decibels

DOGGY DIFFERENCES

Some of the physical characteristics that separate wolves and dogs

7 BARK OR HOWL
Although wolves have the physical ability to bark in a similar way to dogs, it's a relatively rare occurrence. Howling is a wolf's preferred way to communicate.

6 SIMILAR MOUTHS
Both wolves and dogs have 42 teeth. However, wolf teeth are larger and stronger, designed to break bones.

4 BIGGER BRAIN
Domestic dogs generally have smaller brains than wolves, even among breeds that have a comparable body size to wolves.

5 EYE COLOUR
Wolves have yellow eyes, whereas dogs typically have either brown or blue eyes.

8 BECOMING AN ADULT
Wolves reach maturity between two and three years old, whereas dogs can reproduce after only eight months.

3 ELBOWS TOGETHER
Wolves tend to have a narrower chest, and their elbows sit closer together.

2 TAIL WAGGING
Both wolves and dogs display tail wagging as a greeting behaviour.

Dogs and grey wolves share the same prehistoric ancestor

FLOPPY EARS AND WHITE COATS

One of the stranger changes that's occurred during the transition from wolf to dog is their appearance. In the 1950s, Russian scientist Dimitri Belyayev investigated the role of domestication in altering the physical appearance of a generation of wild silver foxes (*Vulpes vulpes fulva*), a member of the dog family. Over 40 years, Belyayev and his research team selectively bred foxes that showed increasing tameness towards humans. Over time, they discovered that the coats of the foxes changed colour, they developed floppier ears, lost their fox smell and grew shorter, curlier tails.

Researchers found that a mechanism that regulates adrenaline, called the hypothalamic-pituitary-adrenal axis, had also changed in the foxes. Adrenaline is a hormone that regulates an animal's flight-or-flight response, which in domesticated foxes was greatly reduced when compared to wild foxes. Belyayev concluded that the decreased adrenaline levels resulted in a reduction in fear of humans. Adrenaline is also linked to the production of a pigment called melatonin, which Belyayev suggested contributes to the change in colouration among domestic foxes.

A silver fox from the Belyayev fox facility at the Institute of Cytology and Genetics of the Russian Academy of Science

© Getty

WHY NETTLES STING

The science behind the sting of these common countryside plants

WORDS **AILSA HARVEY**

On first impression, stinging nettles (*Urtica dioica*) aren't a particularly threatening-looking plant. However, if you've ever brushed against their leaves, you'll know all too well the pain they can inflict.

What gives nettles their stinging power is a cocktail of chemicals held within tiny hair-like structures along the plant's leaves. When these structures are broken they release their chemical contents, which penetrate the skin and cause several painful symptoms such as itching, swelling and redness. The initial skin irritation felt when you are stung by a nettle is caused by histamine, which is also responsible for causing other allergic reactions.

Like many other plants, nettles have evolved their stinging abilities as a defence mechanism against herbivorous animals such as deer and rabbits. Nettle venom isn't strong enough to seriously harm a hungry herbivore – it merely teaches them a lesson in avoiding nettles.

Commonly found around hedgerows, woodlands and fields, stinging nettles are much more than vicious plants, as they also play an important role in their ecosystem. Butterflies, for example, use nettles as a place to lay their eggs, and ladybirds and aphids use nettles for shelter and as a source of nutritious food.

Did you know?

Nettles can grow up to 1.2 metres tall

CHEMICAL COCKTAIL

How nettles deliver their irritating venom

1 BREAKAWAY TIP
Across the nettle leaves are spiny hairs called trichomes. The bulbous tip of the trichome breaks off when it's brushed against, revealing the needle-like tube below.

2 INJECTION
The trichome's inner needles are filled with a stinging cocktail of chemicals including formic acid, histamine, serotonin and acetylcholine.

3 ITCHING
An itching sensation and a burning rash can occur following a sting, lasting up to 12 hours.

4 CHEMICAL FACTORY
At the base of the trichome are specialised cells that secrete the stinging chemicals into the trichome needle.

Dock leaves have large, flat leaves and grow in fields and woodlands

DO DOCK LEAVES REALLY WORK?

It's long been believed that grabbing a dock leaf and rubbing it on a wound after a nettle sting will help ease the pain. Dock plants, also known as bitter dock (*Rumex obtusifolius*), are said to produce a sap that contains an antihistamine to combat the effects of nettle stings. However, there's no evidence of such antihistamines or healing chemical properties. The placebo effect has also been cited as a possible explanation for why some people believe dock leaves help treat the stinging sensation and lower the perception of pain.

One way that the dock leaf sap can offer some relief is through evaporative cooling. As the dock sap evaporates over the sting, the skin beneath can experience a cooling sensation that relieves some of the burning irritation on the skin.

A view of a nettle leaf and its many trichomes under a scanning electron microscope

© Alamy / Getty

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WHAT ARE RIP CURRENTS?

Understanding these powerful channels can help prevent you from swimming into danger

WORDS **AILSA HARVEY**

The darker region shows the path of a rip current

Lifeguards often put up a red flag when there's a dangerous rip current, alerting beachgoers not to swim

Rip currents are like the rivers of the sea, transporting water near the shore back out into the ocean depths. The presence of these currents can be hidden by the hectic movements of the surrounding waves. This means that as well as carrying seaweed and debris quickly out to sea, they can rapidly sweep away even the strongest swimmers. Around 80 per cent of all lifeguard rescues are prompted by powerful rip currents pulling a swimmer into danger.

If you find yourself being pulled out to sea by an unsuspected rip current, you should remain calm, focus on staying afloat and, if you can, swim parallel to the shore. Your instincts might tell you to swim towards land, as this is where you're aiming to get to, but the current will be too strong to swim against. Instead aim to move across the current and into slower flowing water next to it. A rip current may only pull you just past the breaking waves, but in some cases they can take you hundreds of metres offshore. The strength of currents can be hard to predict, so it's safest to stay on lifeguarded beaches and not to swim if you see any indication of a rip current.

A similar force to a rip current is a rip tide. The difference between these comes down to their cause and location. While rip currents form between the breaking waves of a beach, rip tides are a result of flowing water entering the sea from rivers and harbours.

Did you know?

Rip currents travel faster than an Olympic swimmer

HOW THEY FORM

What causes the sea's fast-flowing shortcut through the surf?

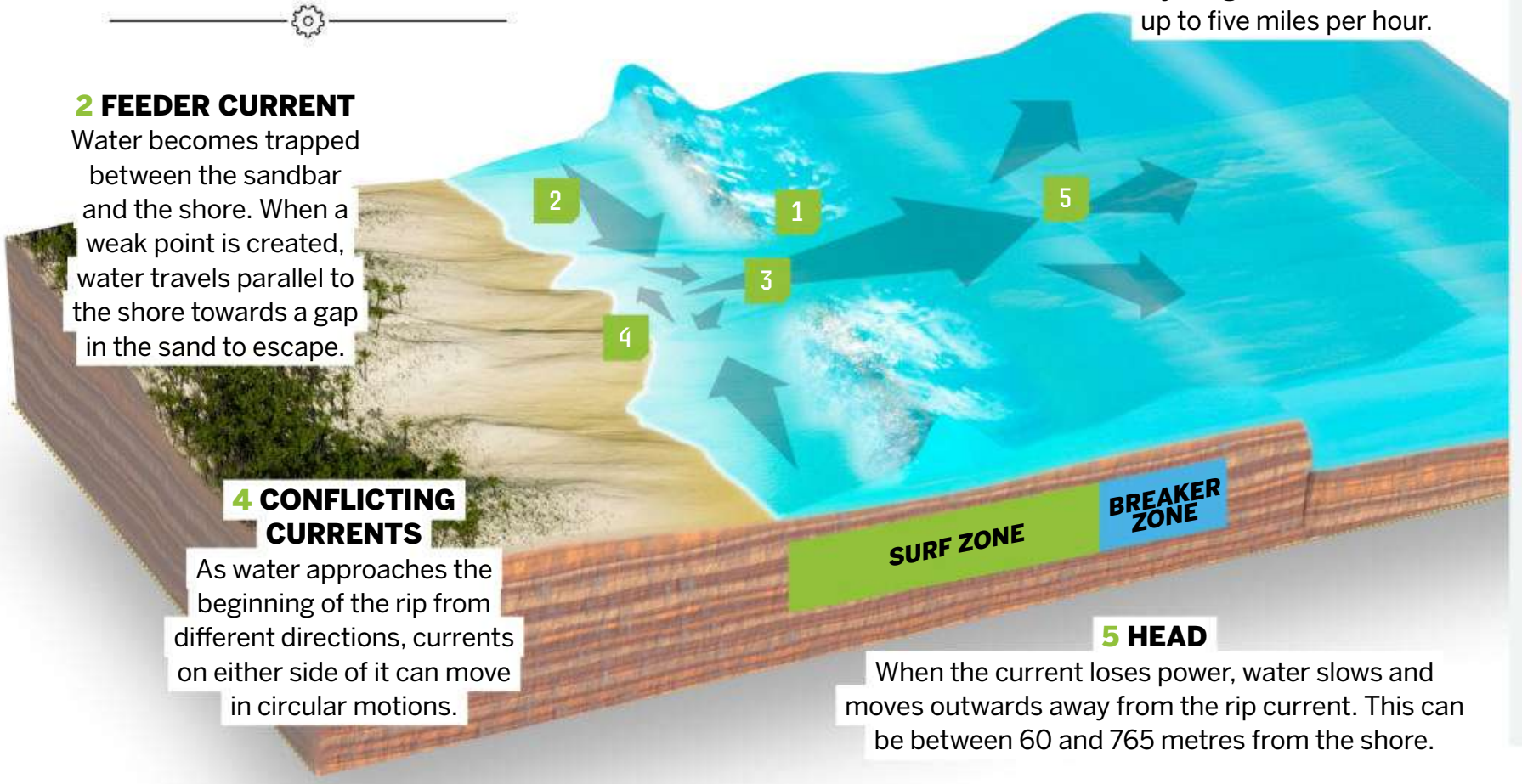
1 CRASHING TO SHORE
Waves break towards the shoreline. As this happens, sand accumulates in one place in the form of a sandbar.

2 FEEDER CURRENT
Water becomes trapped between the sandbar and the shore. When a weak point is created, water travels parallel to the shore towards a gap in the sand to escape.

3 NECK
As water rushes to this point and out to sea, a strong current pulls the water and anything in it out to sea at up to five miles per hour.

4 CONFLICTING CURRENTS
As water approaches the beginning of the rip from different directions, currents on either side of it can move in circular motions.

5 HEAD
When the current loses power, water slows and moves outwards away from the rip current. This can be between 60 and 765 metres from the shore.



5 SIGNS OF A RIP CURRENT

1 DARKER WATER
Where the water is deeper, the water also appears darker. Dark lines sometimes show the path of a rip current.

2 FEWER BREAKS
A rip current often prevents waves from breaking. Gaps in white water can indicate the presence of a rip.

3 SANDY WATERS
If the water appears sandy past the breaking waves, this is a sign that a current is moving offshore and bringing sand up to the surface.

4 DEBRIS EVIDENCE
Follow the movement of floating debris or seaweed. Rip currents will pull these towards them and then out to sea with the current.

5 SURFACE MOVEMENT
As water is rushing towards a single point from different directions, more ripples form at the surface than in the surrounding water.

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				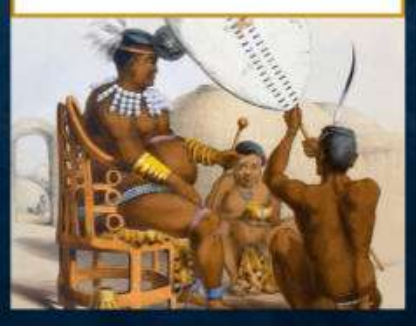

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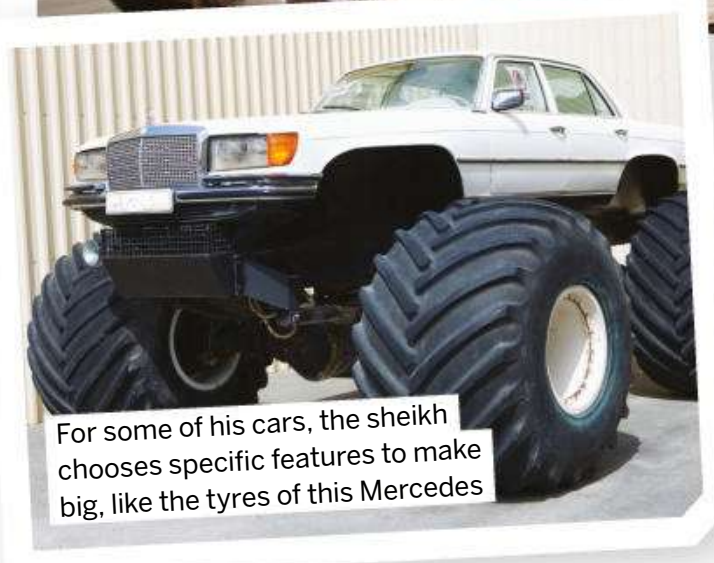
WORDS **AILSA HARVEY**

MONSTER VEHICLES

Meet the supersized submarine, mammoth mining vehicle and other record-breaking machines taking to the roads, seas and sky

DID YOU KNOW? The hydrogen-powered nuGen truck keeps 700 cars' worth of CO_2 emissions out of the atmosphere

This giant pickup truck houses four bedrooms, a kitchen, bathroom and lounge



For some of his cars, the sheikh chooses specific features to make big, like the tyres of this Mercedes

PICKUP POWER

Known as Rainbow Sheikh, billionaire and Emirati royal family member Hamad bin Hamdan Al Nahyan of Abu Dhabi owns over 200 cars. And many of these are not ordinary cars, but supersized automobiles.

One of these is the world's biggest truck, a 1950 Dodge Power Wagon pickup truck replica that's 64 times larger than the original. As part of the construction of this monster vehicle, wheels were taken from a huge vehicle that was used to transport oil rigs. The wiper blades came from the expansive windows that front a captain's cockpit on an ocean liner.

This isn't the only monster car that the sheikh has in his collection. Further fascinating designs include a double-sized Jeep Wrangler, which is a giant vehicle made up of two jeeps joined at the sides; the world's largest Humvee and a massive sports utility vehicle.

Did you know?

The sheikh's pickup truck weighs 50 tonnes

GIANT GREEN MACHINE

As vehicles grow in size, so do their emissions. But not all large vehicles follow this environmentally damaging trend. The nuGen hybrid 290 T-class mining truck is the world's largest hydrogen-powered truck, working at the Mogalakwena platinum mine in South Africa. The 220-tonne truck is equivalent in height to a three-storey building. To achieve a zero-emission vehicle at such a large scale, mining firm Anglo American installed a two-megawatt hybrid battery and hydrogen fuel cell power plant into a truck that was previously diesel-powered. The hydrogen in the fuel cell reacts with oxygen to produce power. As a result, the only emission is water vapour.

Did you know?

The nuGen hybrid 290 t class is around ten metres tall

The nuGen hydrogen truck can carry a 290-tonne payload

© Alamy / Getty

A prototype of the world's biggest transport helicopter being loaded with a fire engine

The open cargo bay doors of the Mi-26T2V, showing its cavernous interior

Did you know?

The Mi-26T2V has an eight-blade rotor, a world first

HEFTIEST HELICOPTER

The Mil Mi-26T2V is 40 metres long and weighs 28,000 kilograms

1 MAIN ROTOR BLADES
The diameter of the main rotor is 32 metres.

2 TROOPS
The heavy-lift transport helicopter can carry 82 people and their equipment or heavyweight military vehicles.

5 ENGINE EXHAUST
Air enters the helicopter near the cockpit, and exhaust fumes are released here at both sides of the aircraft.

7 TAIL ROTOR
There are five blades making up the tail rotor.

6 TWO ENGINES
In this compartment are two D-136-2 turboshaft gas turbine engines. The helicopter is designed so that it can still fly even if one fails.

3 CARGO COMPARTMENT
The aircraft can carry 20 tonnes of cargo.

4 RADAR ANTENNA
Just behind the nose of the Mi-26T2V is a radar antenna. Radio waves are sent out through the front of the helicopter to detect other aircraft.

5 BIGGEST SHIPS ON THE OCEAN

CONTAINER
The Ever Ace is the world's largest container ship. At 400 metres long, the ship can carry 23,992 standard-sized containers.

CRUISE
The largest cruise ship, Wonder of the Seas, was launched in 2020 and can carry 6,998 guests. It is over 340 metres long.

LARGEST LAND VEHICLE

At first glance, the world's largest land vehicle appears to defy gravity. Extending from the core of the Bagger 288, a 22-metre-wide jagged wheel hangs in the air. Its target? Earth. Bagger 288 is a bucket-wheel excavator used to rapidly remove earth during mining. As the wheel spins against the ground, the 18 buckets evenly distributed around the perimeter of the wheel collect earth and release it into the vehicle's three-metre-wide conveyor belts, which carry it away. The wheel doesn't need to be stopped after each retrieval, making mining efficient. 240,000 cubic metres of soil can be removed in one day.

This monstrous contraption measures 95 metres high and 215 metres long. But what Bagger 288 boasts in size it lacks in speed, as it can only travel at 0.4 miles per hour. However, for its role in the coal mine, its excavation rate is valued much higher. Bagger 288 is owned by the energy company RWE AG as part of a fleet of vehicles of the same size.

Bagger 288 is used for open-cast coal mining

Did you know?

Bagger 288 weighs 40,000 tonnes

The nose of the Antonov An-225 lifts upwards for entry to the cargo hold

Antonov An-225 was severely damaged in Russia's invasion of Ukraine

Antonov An-225 was 84 metres in length and had a wingspan over 88 metres

WHAT HAPPENED TO THE WORLD'S LARGEST PLANE?

The Antonov An-225 was the world's largest plane, with six engines and a giant cargo hold space measuring 43 by 6.4 metres. Referred to as 'Mriya', which means 'dream' in Ukrainian, the aircraft's size allowed it to break over 200 flight records, such as carrying the longest airlifted cargo as well as the heaviest freight. Only one Antonov An-225 was built. Since its completion in 1988, the aircraft was a vital tool in carrying large and unusually shaped cargo. However, on 20 May 2022 the plane was destroyed during the Russian invasion of Ukraine. A rebuilding of the aircraft is planned, but is estimated to take five years and cost around £2.4 billion ($3 billion).

Did you know?

The Antonov's first flight was on 21 December 1988

CRANE SHIP

SSCV Sleipnir is a vessel holding two giant cranes, each of which is capable of carrying 10,000 tonnes. It can hold 4,000 workers.

ORE CARRIER

MS Ore Brasil is the biggest ore carrier, capable of transporting 11,150 trucks' worth of iron ore from Brazil.

SOLAR-POWERED VESSEL

With 38,000 solar voltaic cells, the MS Tûranor PlanetSolar is the world's largest solar-powered ship.

© alamy / Getty / Wiki: Superfast1111

LONGEST SUBMARINE

Take a look inside Russia's giant nuclear submarine, K-329 Belgorod

1 TOWED SONAR ARRAY
A cable attaches to this point to hold a sonar array behind the vessel. The sonar array sends out sound waves to detect other boats and objects in the water. It's towed to prevent interference from the submarine itself.

6 HANGAR
Smaller autonomous underwater vehicles called Klavesin are stored in a compartment at the top of the submarine until they're deployed.

2 SCREWS
These propellers, or screws, drive the submarine. Belgorod's screws were designed to be undetectable by sonar, preventing enemies from pinpointing the vehicle's location.

3 WATER SCOOPS
The submarine's large motors and generators need to be cooled. Seawater is drawn into the vehicle here and circulated around these components.

4 NUCLEAR POWER
The submarine is powered by the OK-650 pressurised-water nuclear reactor.

11 MINI-SUB
Two miniature submarines can dock to Belgorod's belly.

DID YOU KNOW? 1,700 metres of electric cables are connected to Bagger 288

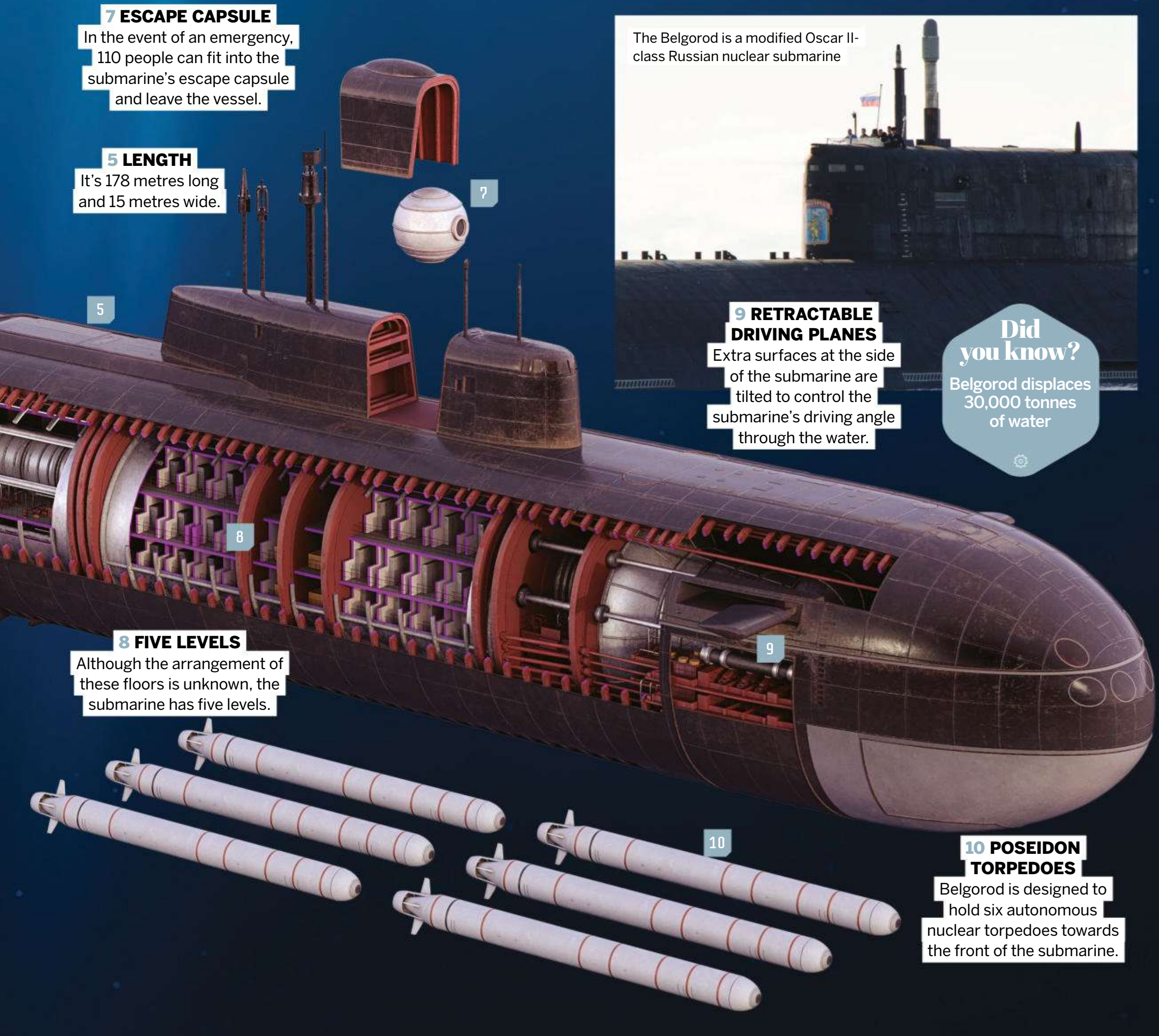
LONGEST TRAIN

If you're a regular rail commuter, you'll expect most trains to arrive at the station with a few coaches – maybe ten for a long train – and this is usually enough to fill most of a station's platform. The longer a train, the more skill is required by the train driver to keep control of the vehicle. In May 2022, this skill was tested at extreme lengths when 100 coaches were driven across mountainous terrain. It broke the record for the world's longest passenger train at 1.2 miles long and was driven 15.5 miles along a winding track in Switzerland. Seven drivers were required to keep control of the extensive carriage line so that the speed of each section was synchronised along the uneven tracks.

On the day of the world record confirmation, the train left from Preda train station in Switzerland

Did you know?

The Rhaetian Railway train had seating for 4,550 passengers



7 ESCAPE CAPSULE
In the event of an emergency, 110 people can fit into the submarine's escape capsule and leave the vessel.

5 LENGTH
It's 178 metres long and 15 metres wide.

8 FIVE LEVELS
Although the arrangement of these floors is unknown, the submarine has five levels.

10 POSEIDON TORPEDOES
Belgorod is designed to hold six autonomous nuclear torpedoes towards the front of the submarine.

The Belgorod is a modified Oscar II-class Russian nuclear submarine

9 RETRACTABLE DIVING PLANES
Extra surfaces at the side of the submarine are tilted to control the submarine's driving angle through the water.

Did you know?

Belgorod displaces 30,000 tonnes of water

© Alamy / Illustration by Nicholas Forder / RhB;Philipp Schmidli

INSIDE THE ASTEROID BELT

The gap between Mars and Jupiter has no planets, and it's surprisingly interesting for it

WORDS ANDREW MAY

DID YOU KNOW? One of the asteroid-hunting groups of the early 19th century called themselves the Celestial Police

Asteroids are chunks of rock, ranging in size from hundreds of miles down to a few metres across, that orbit the Sun like miniature planets. While a few of the largest asteroids have a roughly spherical shape, most of them are much more irregular in appearance. To date, more than a million asteroids have been discovered – the majority of them in the main asteroid belt sitting between the orbits of Mars and Jupiter. The asteroid belt is one of the Solar System's most important features, marking the boundary between the two different types of planets: the rocky inner planets Mercury, Venus, Earth and Mars, and the giant outer planets Jupiter, Saturn, Uranus and Neptune. It's also the widest swathe of the Solar System between the orbits of Mercury and Neptune that is entirely planet-free.

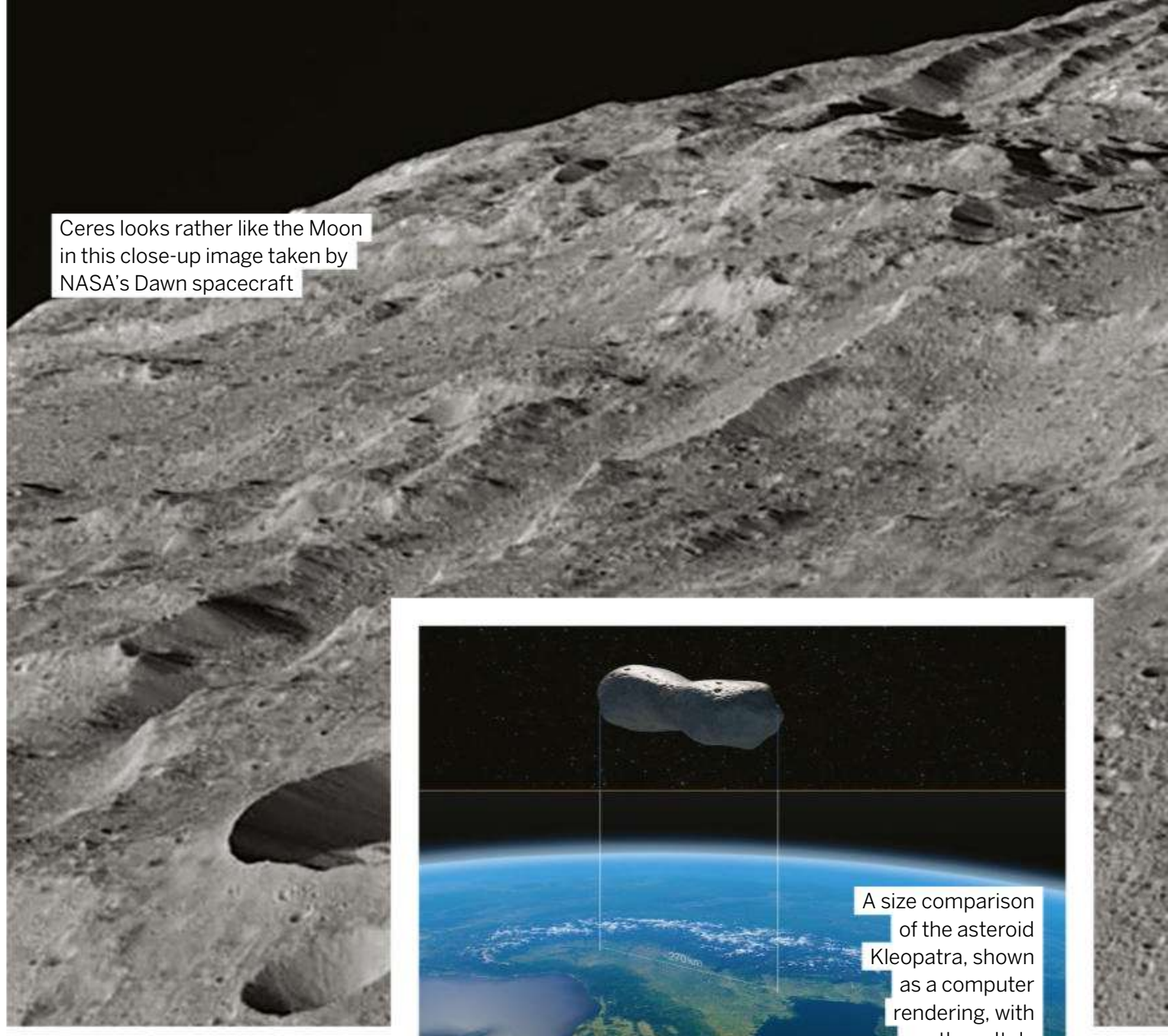
The lack of planets in the region between Mars and Jupiter was a puzzle for early astronomers, and many of them were convinced there had to be a hitherto unknown planet there. By the end of the 18th century, the hunt for this supposedly missing planet had become something of a competition between rival groups of astronomers. The apparent winner was Giuseppe Piazzi of Palermo Observatory in Sicily, who found a planet-like object in the right sort of area on 1 January 1801. But doubts were cast almost immediately.

©Getty

For one thing, the new object – which Piazzi called Ceres – appeared much too small to be a proper planet. For another, Ceres wasn't alone. Over the next few years, astronomers found three more objects – Pallas, Juno and Vesta – in the same region of space. What had been discovered wasn't the expected 'missing' planet, which didn't exist, but something completely new to science: the asteroid belt. By 1850, ten objects had been found there, and over 200 more were identified in the 30 years after that. By the 20th century, so many asteroids were known that they were referred to as the 'vermin of the sky', and new discoveries continue to this day.

The word asteroid means 'starlike', but this refers to their appearance through a telescope as small points of light rather than their physical nature. Even through a telescope the difference soon becomes obvious, because asteroids – like planets – move relative to the backdrop of the much more distant stars. Asteroids are also like planets in that they only shine by reflecting light from the Sun.

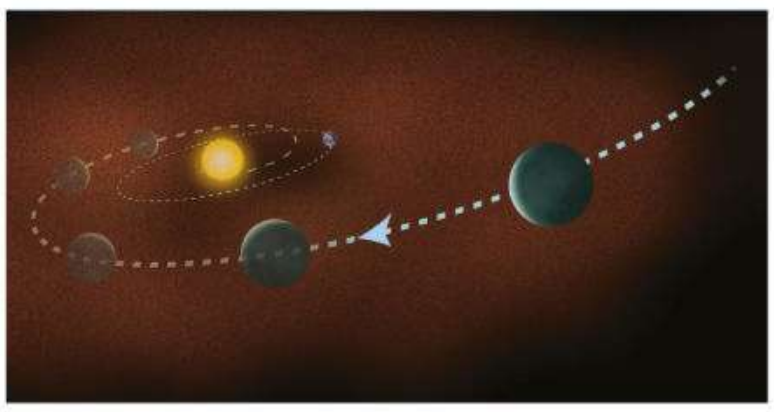
The upper and lower size limits of asteroids are relatively vague. At the low end they merge with meteoroids – pebble-sized pieces of rock



Ceres looks rather like the Moon in this close-up image taken by NASA's Dawn spacecraft

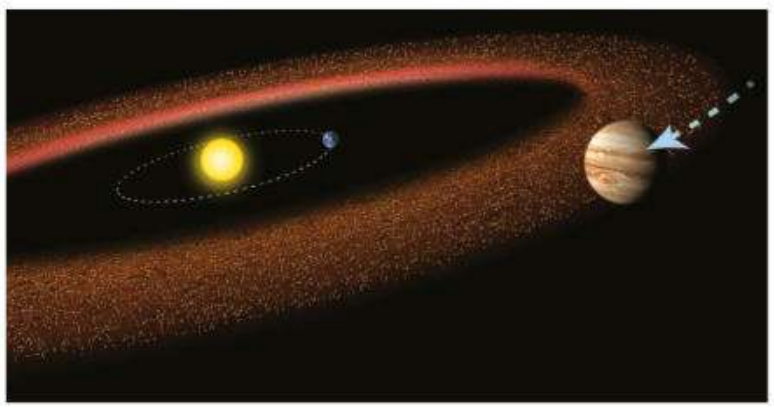
A size comparison of the asteroid Kleopatra, shown as a computer rendering, with northern Italy

EVOLUTIONARY THEORIES



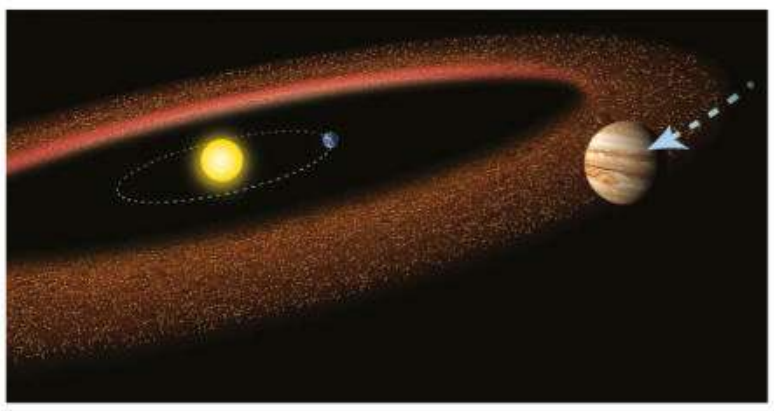
Disrupted belt

If a large Jupiter-like planet was formed on the outskirts of a planetary system and then migrated inwards through the asteroid belt, it would deflect material onto the inner planets. Impacts would likely inhibit the development of life on these planets.



Solar system belt

This is the situation in our own Solar System. Jupiter did migrate slightly inwards, but stopped outside the main asteroid belt. This allowed the planets further in to remain stable and undisrupted.

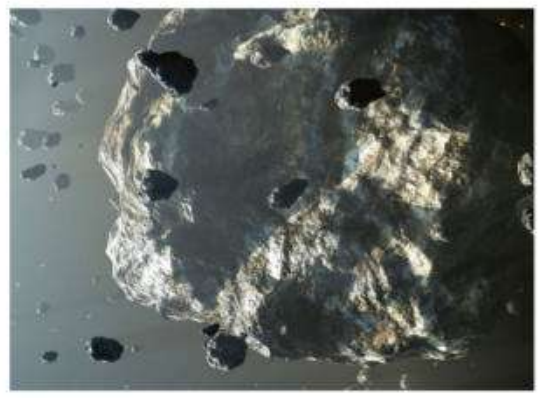


Dense belt

If Jupiter didn't migrate inwards at all, the resulting asteroid belt would be denser. It's likely that material from it would periodically bombard the inner planets, and this again would inhibit any life from evolving on them.

HOW DENSE IS THE ASTEROID BELT?

Because there are millions of objects in the belt, it's tempting to picture it as a densely packed, crowded place. That's how it's often portrayed in science fiction and even scientific visualisations. But the asteroid belt occupies a huge volume of space, so all those objects are spread out very thinly. It's likely that, seen from one asteroid, its nearest neighbour would be too far away to be seen without a telescope. The huge gaps between asteroids also mean it's highly unlikely that a spacecraft passing through the asteroid belt would collide with anything larger than a grain of interplanetary dust.



Visualisations make the asteroid belt look much more crowded than it is

DID YOU KNOW? NASA has detected not one, but two asteroid belts around the star Epsilon Eridani, ten light years away

found everywhere in the Solar System – and at the upper end with full-blown rocky planets. Piazzi's original discovery, Ceres, remains the largest object in the asteroid belt, and for a long time it was simply thought of as a very large asteroid. However, in 2006 it was reclassified as a dwarf planet due to its unusual size; Ceres actually contains a quarter of the entire mass of the asteroid belt.

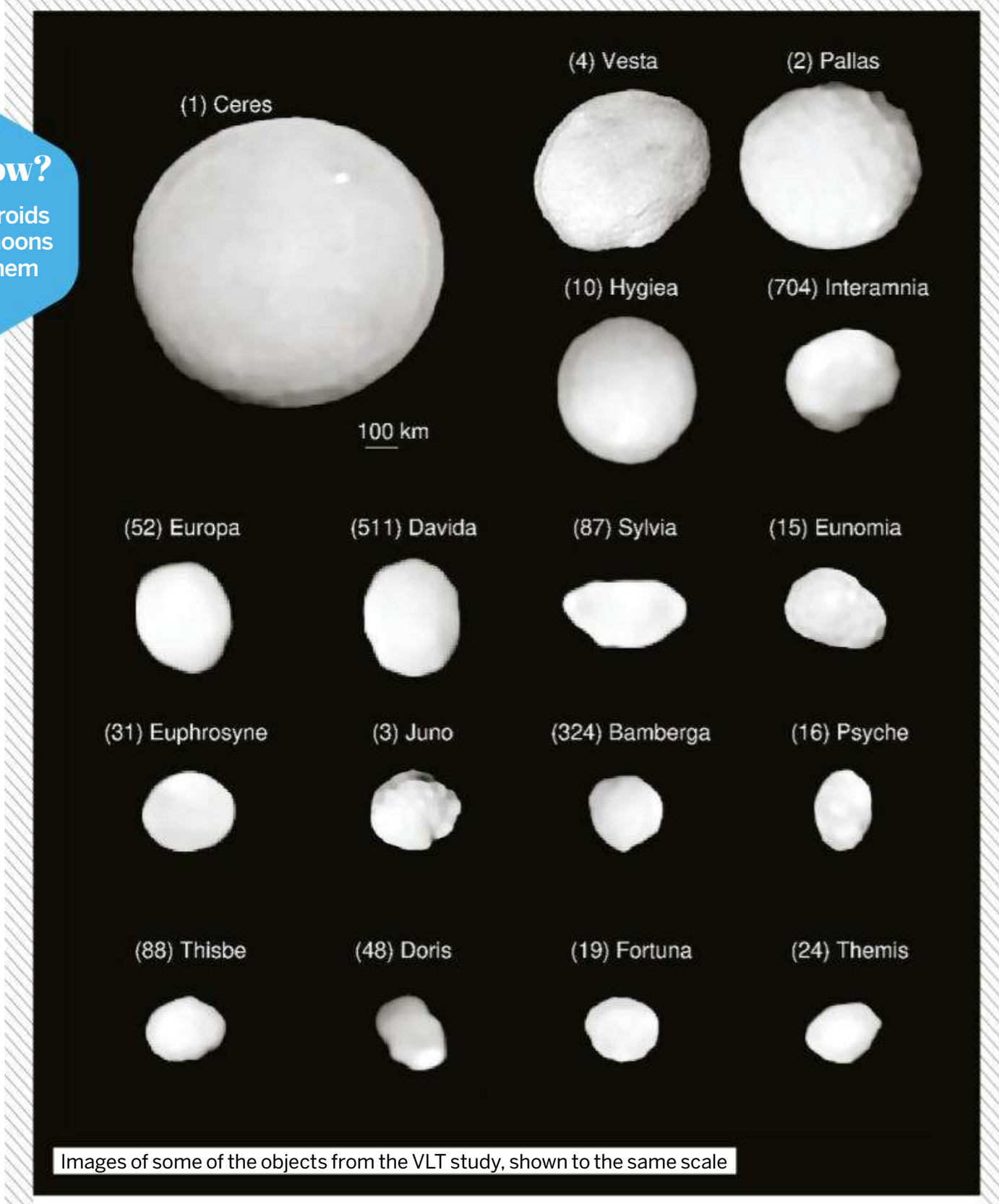
Did you know?

Some asteroids have tiny moons orbiting them

Asteroids in general come in a variety of types depending on their chemical composition. The most common type, encompassing more than three-quarters of all known asteroids, are carbonaceous, or C-type, asteroids. These are particularly prevalent in the outer regions of the asteroid belt. The inner region, on the other hand, has more siliceous, or S-type, asteroids, while metallic, or M-type, asteroids are found in the central regions of the asteroid belt.

Not all asteroids are confined to the main asteroid belt between the orbits of Mars and Jupiter. While the asteroids there tend to travel on more or less circular orbits, others appear to have been diverted onto smaller and more elliptical orbits that take them past Mars into the inner parts of the Solar System, close enough to the orbits of the inner planets – including Earth – that they can occasionally pose a collision risk. Scientists believe these rogue asteroids did originate in the main asteroid belt, but were subsequently deflected by the substantial gravitational effects of the giant planet Jupiter onto their current much more eccentric orbits.

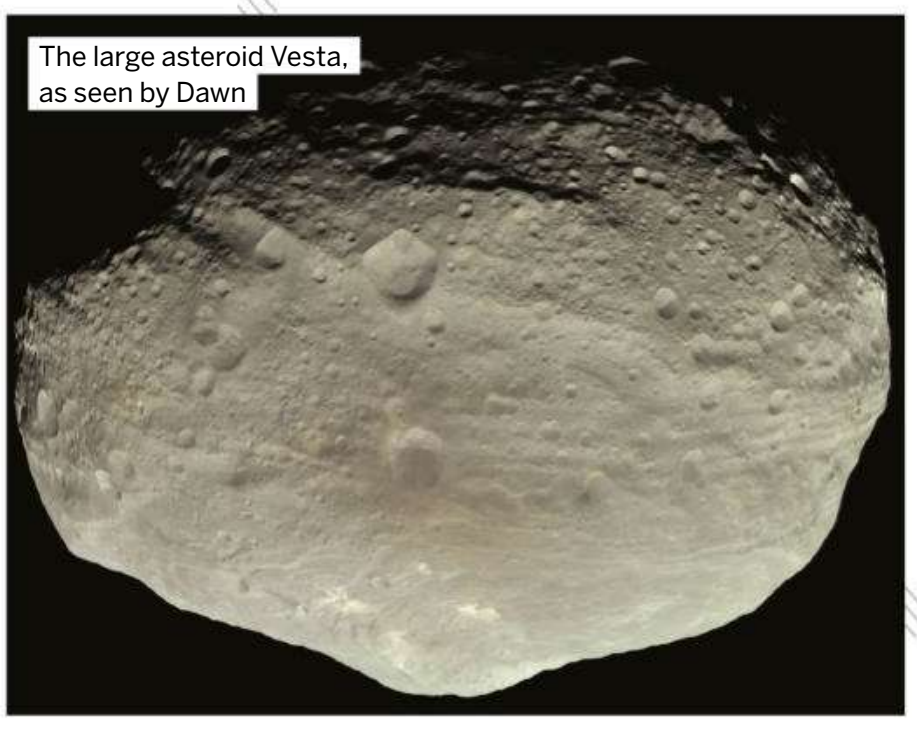
Jupiter's gravity is an important key to understanding the current appearance of the asteroid belt. It probably originated very early in the history of the Solar System – a few tens of millions of years after the Sun was born – when the entire inner part of the Solar System would have been filled with rocky asteroid-like bodies. Many of these eventually coalesced to form the planets Mercury, Venus, Earth and Mars – and the real mystery is why the same process didn't result in another similar planet between Mars and Jupiter. The most important reason seems to be that the strong pull of Jupiter's gravity is constantly stirring things up in the asteroid belt and preventing any further planet formation. On top of that, despite the large number of individual asteroids, the actual quantity of matter in this region is very small, with all the asteroids put together only amounting to around four per cent of the Moon's mass. It's likely that this paucity of material can be attributed to the effects of Jupiter too, which slowly stripped the original asteroid belt of most of its mass.



Images of some of the objects from the VLT study, shown to the same scale

THE LARGEST OBJECTS IN THE ASTEROID BELT

We know much more than we did a few years ago about the largest objects in the asteroid belt thanks to a 2021 study that used data from the European Southern Observatory's Very Large Telescope (VLT) to characterise their three-dimensional structures. In particular, the study measured an object's diameter, density and flattening – the latter being the ratio of its smallest dimension to its largest. The biggest object, as expected, was the dwarf planet Ceres, with a diameter of 584 miles, a density of 2.2 grams per cubic centimetre and a flattening ratio of 0.92. The closeness of the flattening ratio to 1.0 means that Ceres is relatively spherical, although Hygiea, with a flattening ratio of 0.94, is even rounder. The most elongated object the study measured was Kleopatra, with a flattening of just 0.18, while the densest was the metal-rich asteroid Psyche, at 3.9 grams per cubic centimetre.


The large asteroid Vesta, as seen by Dawn

© Alamy / NASA / European Southern Observatory

VISITING THE ASTEROID BELT

Several previous and planned NASA missions have been designed to explore this part of the Solar System

> "Dawn contributed to a greater understanding of how early planetesimals formed"

MISSION TO A METAL ASTEROID

Psyche is one of the largest objects in the asteroid belt, measuring some 140 miles across. It's also one of the most intriguing because it appears to be composed largely of metal. That's the main reason why NASA has chosen it as the destination for its next mission to the asteroid belt, which will likewise be called Psyche. While using cameras to show us what the asteroid looks like, the Psyche spacecraft will also carry a number of scientific instruments to probe its surface composition, which is believed to include iron, nickel, silicon and oxygen. These resemble what might be found in the core of a small planet, and it's possible that's just what asteroid Psyche is, having had its outer layers stripped off by collisions early in the Solar System's history.

As well as exploring the asteroid to learn everything it can tell us about planetary formation, the Psyche mission also has a secondary objective to test a new technology called 'deep-space optical communication'. This uses infrared laser beams to carry messages between the probe and Earth, allowing more data to be transmitted in a given time than traditional radio communication.

NASA's original plan was to launch the Psyche spacecraft in 2022, but this wasn't possible due to teething problems with its flight software. The hope now is that it will be launched in October 2023, which would put it on track to arrive at its namesake asteroid in August 2029.

The Psyche spacecraft being assembled in a cleanroom at NASA's Jet Propulsion Laboratory

ASTEROID PROBE

NASA's Psyche spacecraft will study the similarly named asteroid from close quarters

6 MAGNETOMETER
This instrument measures the magnetic field strength around the asteroid.

7 MULTISPECTRAL IMAGER
This uses the same technology as the Mastcams on NASA's Mars rovers.

4 OPTICAL COMMUNICATIONS
This is a prototype system designed to test laser-based communications as an alternative to radio.

5 GAMMA-RAY AND NEUTRON SPECTROMETERS
These sensors provide data on the chemical abundances of metals in the asteroid.

3 HIGH-GAIN ANTENNA
This traditional radio dish is the spacecraft's primary means of communication with Earth.

1 ASTEROID
The spacecraft will orbit around Psyche at distances down to 53 miles.

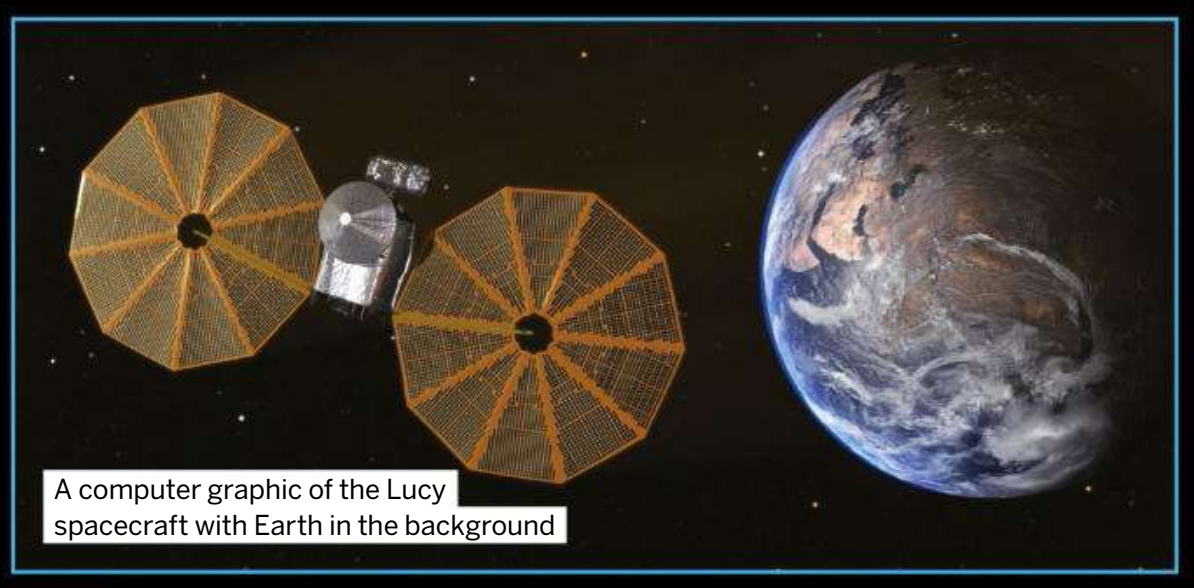
2 SOLAR PANELS
These provide power both for the spacecraft's internal electronics and its solar-electric propulsion system.

DID YOU KNOW? Based on its probable metal content, asteroid Psyche is worth an estimated 10 quintillion dollars

Deep Space 1

Launched in October 1998, NASA's Deep Space 1 used a novel form of ion propulsion called solar-electric propulsion, the power for which comes from a large array of solar panels. This approach, now common in deep-space missions, provides significant mass savings over more traditional propulsion methods. As well as successfully demonstrating the new technology, Deep Space 1 performed flybys of both a comet and an asteroid. The latter, named Braille, moves on an eccentric orbit from inside the orbit of Mars to the outer regions of the main asteroid belt.

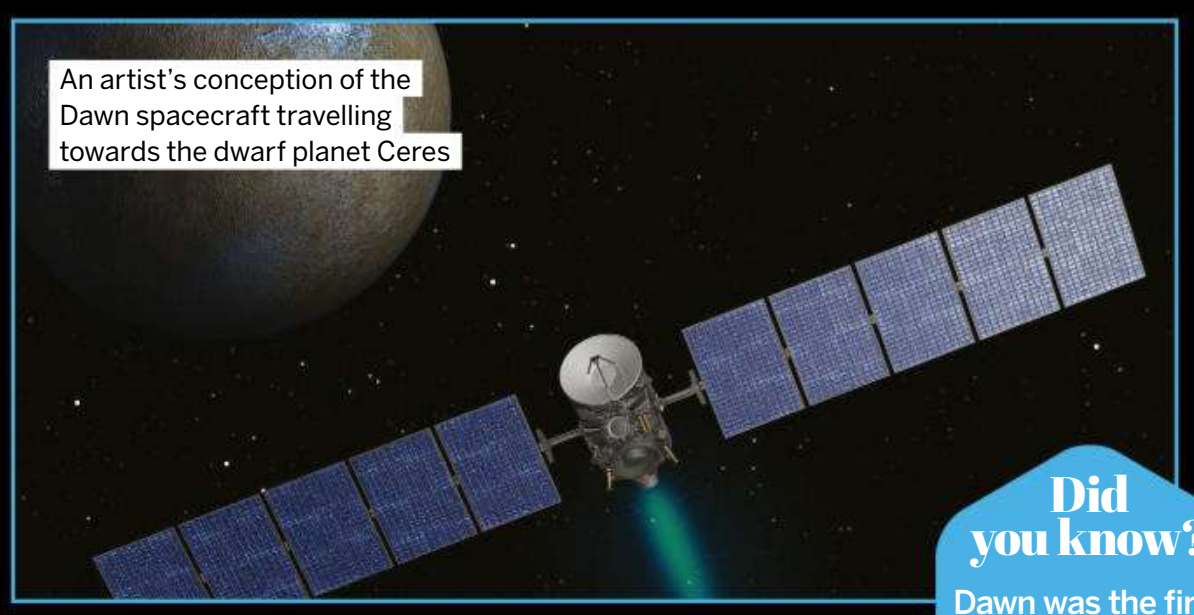
A NASA rendering of the Deep Space 1 spacecraft in flight



A computer graphic of the Lucy spacecraft with Earth in the background

Lucy

Launched in October 2021, NASA's Lucy probe is heading off to study a number of asteroids – but most of them aren't in the main asteroid belt. They're called 'Trojan asteroids', and they share the same orbit around the Sun as Jupiter, though in two groups travelling ahead of and behind the planet itself. However, Lucy's first destination, as it files en route to the Trojans, is a small main-belt asteroid named Donaldjohanson, after a fossil hunter who found the skeleton of a prehistoric human ancestor he called Lucy. The spacecraft is expected to get there in 2025.



An artist's conception of the Dawn spacecraft travelling towards the dwarf planet Ceres

Did you know?

Dawn was the first craft to orbit two destinations

Dawn

Launched in 2007, Dawn remains NASA's most important mission to the asteroid belt so far. Using similar ion drive technology to Deep Space 1, it was able to visit the belt's two largest objects – Ceres and Vesta – and rather than simply flying past, it spent time orbiting them so it could study them in detail. Arriving at Vesta in July 2011, Dawn orbited that asteroid for 14 months before moving on to dwarf planet Ceres, where it arrived in March 2015. It remains in orbit there now, although its active mission ended in 2018 when it ran out of fuel.

Carol Raymond and Julie Castillo-Rogez, senior scientists at NASA's Jet Propulsion Laboratory

HIGHLIGHTS OF THE DAWN MISSION

Two of the scientists involved in this major mission to the asteroid belt give us their insights

When Dawn arrived at Vesta, did it look the way you expected?
Vesta looked very familiar since it had been observed extensively by telescopes. Hubble data had shown a giant crater near Vesta's south pole. Dawn's examination revealed there were two overlapping impact basins, one very old and the other relatively young. Vesta was known to be very bright, but a dark patch rich in hydrated minerals was discovered that is the remnants of the earlier, carbon-rich impactor.

Is Ceres similar to Vesta?
Ceres and Vesta differ in fundamental ways, largely due to when and where they formed. Vesta formed very early in the inner Solar System and experienced melting, leaving it dry and differentiated into core, mantle and crust. Ceres formed less than 2 million years later in the outer Solar System from ice-rich material and didn't experience temperatures high enough to melt it. As Ceres evolved, water-rock reactions resulted in a global subsurface brine layer beneath a crust rich in ice and clay-like minerals. Patches of bright material that dot Ceres' relatively smooth surface are from these subsurface brines.

How has Dawn contributed to our understanding of the asteroid belt?
Dawn contributed to a greater understanding of how early planetesimals formed. These results support the idea that large protoplanets formed rapidly from collapsing clouds in the protoplanetary disc. Many, if not all, water-rich asteroids likely migrated from colder regions. The discovery of brine activity on Ceres persisting to recent times provides new constraints on how other large icy bodies evolve and may create habitable environments.

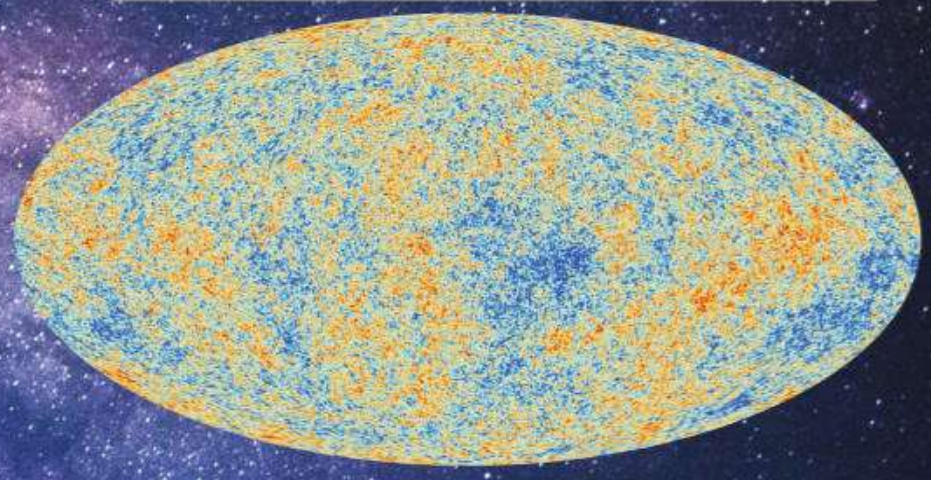
©NASA / JPL

WHAT'S AT THE EDGE OF THE UNIVERSE?

Discover the size of the known universe and what might lie beyond

WORDS **SCOTT DUTFIELD**

A map of cosmic microwave background radiation taken by the European Space Agency's (ESA) Planck satellite in 2013



Around 13.8 billion years ago, the universe and everything that exists within it erupted from a single, infinitely hot and dense point. This is known as the Big Bang. Our understanding of the universe is divided into the observable universe and the unobservable universe. The word 'universe' is often used to describe everything in existence, including all the matter and energy within space. However, we can't see the entire universe from Earth, and so we refer to what we can see as the observable universe, the edges of which are called the cosmic horizon.

The reason we have a limited view of what exists in the universe, albeit billions of light years into space, is due to a principle in physics known as cosmic inflation. Since the Big Bang, space itself has been expanding in every direction from that single point, and at a rate much faster than the speed of light. So many objects that were at the edge of the universe to begin with have since moved into the unobservable part of the universe – the light emitted by them will never reach us. It also means that the cosmic horizon and the observable universe has grown when light from the farthest reaches of space finally reaches us. Each year the cosmic horizon expands by about 38 trillion miles, or 6.5 light years.

There are many different theories about what's beyond the cosmic horizon of the observable universe. Some believe that there are many more of the same types of galaxies and star clusters that we see in the observable universe. We often think of the observable universe as a sphere, however, what we see is only a portion of the wider observable universe, the shape of which might be flat. Einstein's theory of general relativity tells us that space can curve and that the universe is one of three shapes: flat, spherical or saddle-shaped. The shape of the universe also determines whether it's infinitely long or if it's finite, and curves back on itself to form a sphere.

To understand the size and shape of the universe, astrophysicists turn to a remnant of the Big Bang called the cosmic microwave background (CMB). Following the initial period of expansion, an afterglow of radiation was left behind, known as the CMB and dating back to about 400,000 years after the Big Bang. The CMB can't be seen by the naked eye, and can only be revealed by looking at the microwave portion of the electromagnetic spectrum. Variations in the temperature of the CMB allow scientists to measure the geometry of space as it expands. Although it's still debated among scientists, CMB measurements thus far suggest that the universe beyond our observable edges is flat.

Did you know?

The speed of light is 299,792,458 metres per second

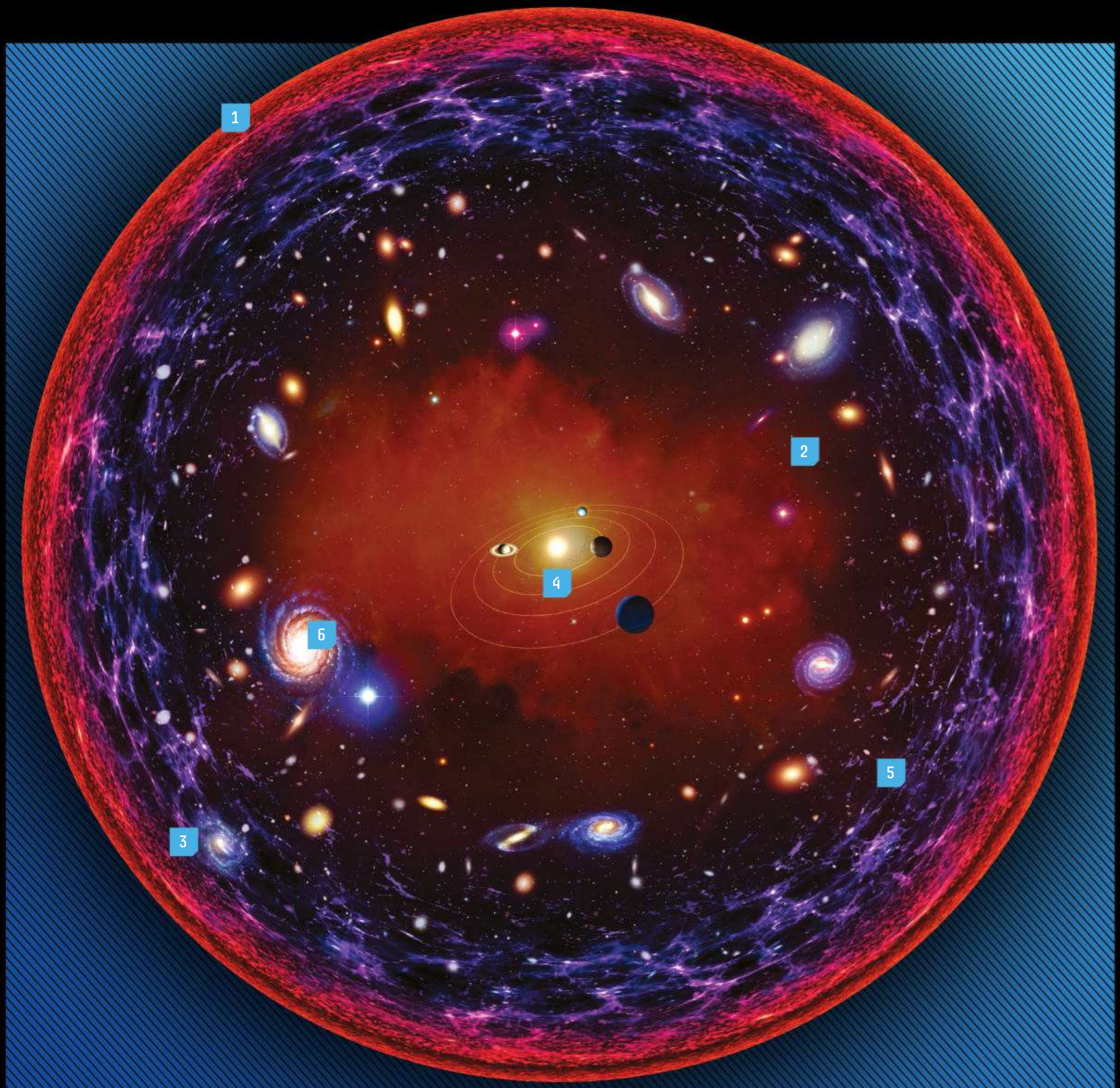
BORDERLANDS

Could we ever travel to the edge of the observable universe and go beyond?

There are several laws of physics we would have to find a way around before any intrepid astronauts could journey this deep into space. Firstly, we'd have to combat the expansion of the universe. Due to the rate of cosmic inflation surpassing the speed of light, we'd have to create an engine that can move quicker than the speed of light and beat the rate of cosmic inflation to reach beyond the cosmic horizon. Unfortunately, no such physics-bending machine exists. In a scenario whereby physics is our only limitation, current estimates suggest that the farthest a rocket could travel in space is less than 18 billion light years from Earth.

A spacecraft travelling faster than light may be able to travel beyond the edge

DID YOU KNOW? The universe as we know it was discovered in the 1920s by revolutionary astronomer Edwin Hubble



SIZE OF THE UNIVERSE

The entire observable universe as we know it

1 COSMIC HORIZON
Much like the horizon over the sea, the cosmic horizon is home to the farthest galaxies that we can observe.

2 LOOKING AT A LOT
It's estimated that the observable universe – if it's a sphere – is around 93 billion light years in diameter.

3 FARTHEST GALAXY
The farthest known galaxy from Earth is 13.5 billion light years away. HD1 could contain some of the oldest stars.

4 SMALL SLICE
It's estimated that it's only possible for us to observe around four per cent of the universe; the remaining 95 per cent remains a mystery.

5 COMPOSITION
The known universe is made up of 4.9 per cent atomic, or baryonic, matter; 26.8 per cent dark matter and 68.3 per cent dark energy.

6 GALAXIES
It's estimated that there are around 2 trillion galaxies in the observable universe.

© ESA and Planck Collaboration / Getty

BIOMETRICS EXPLAINED

Get to grips with the technology that can recognise your fingerprints, face and more

WORDS SCOTT DUTFIELD

The term ‘biometrics’ sounds like a futuristic technology used among spies and saboteurs on the big screen. However, it’s far from science fiction, and much more common than you might think. The word biometrics merely relates to the measurement of the biological or physical qualities that are unique to a person. Those measurements can then be used to compare two samples, such as an image of a face, and determine whether or not the two are a match.

Humans have long used individual physical characteristics as a method of identification. In around 29,000 BCE, cavemen used thumbprints to claim ownership of their cave drawings, and Babylonian businessmen used fingerprints as seals on contracts in 1913 BCE, though it wasn’t until the 1700s in Germany that fingerprints’ unique identifiable features were discovered. Over time, early biometrics developed into more complex methods of analysis, such as digital fingerprinting, facial recognition and voice authentication.

DID YOU KNOW? According to HSBC, its voice biometric system prevented £249 million ($308.5 million) from being stolen in 2021

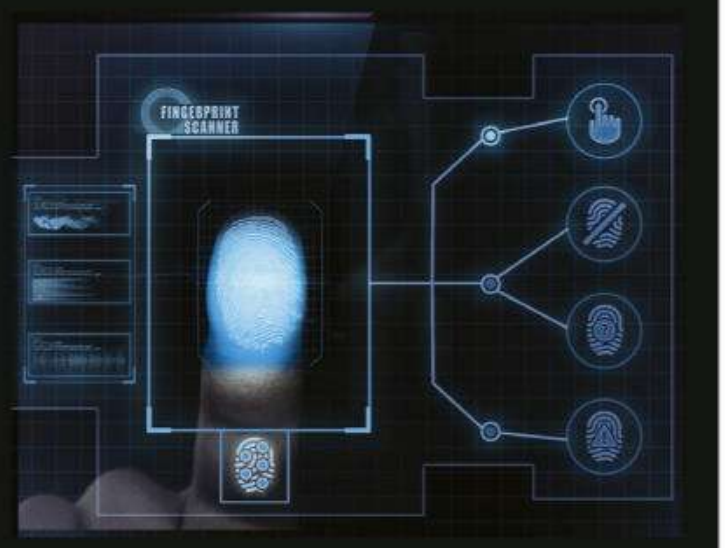
FINGERPRINT SCANNING

Since ditching the ink in the 1970s, fingerprint biometrics have become commonplace for identification, especially in smartphone security. The first modern-day scanners were developed by the Federal Bureau of Investigation (FBI) and used light to take a digital picture of a fingerprint and convert the curves and ridges into binary code, which is formed of ones and zeros. This unique binary code could then be attributed to an individual. Over time, this technology has evolved into capacitive fingerprint scanners that use touchscreen technology to create a digital fingerprint using electrical sensors. Beneath the screen of your smartphone or tablet are tiny electricity-storing capacitors that create a map of tiny contact points. When a finger is placed over the map, fingerprint ridges trigger the sensors and create an identifiable pattern.

Fingerprints aren't the only feature on your hands that can identify you. Known as vein matching or vein pattern recognition, scientists have created a way to identify people based on the unique configuration of veins in their fingers. In a similar way to how optical fingerprinting works, vein matching casts infrared light over a finger to reveal the network of interconnected veins before an imaging sensor captures it for comparison.

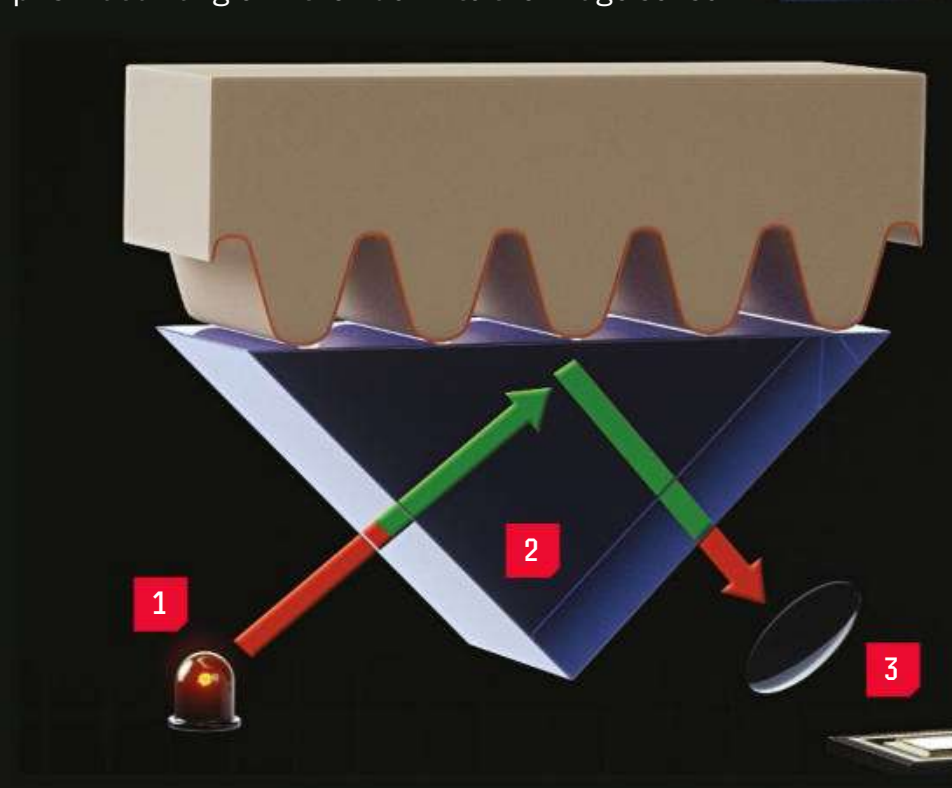
USING YOUR HAND AS ID

How your finger becomes a key



1 LIGHT
An LED emits light that passes through one face of a prism at an angle.

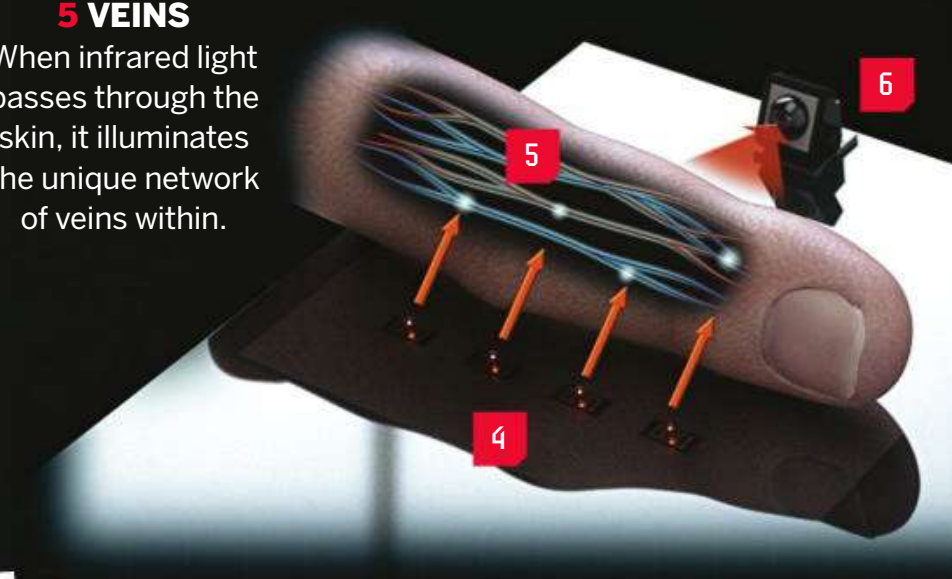
2 PRISM
A prism is used to redirect light from its source to the fingerprint contact point and then down to the image sensor.



Did you know?
Identical twins do not share the same fingerprints

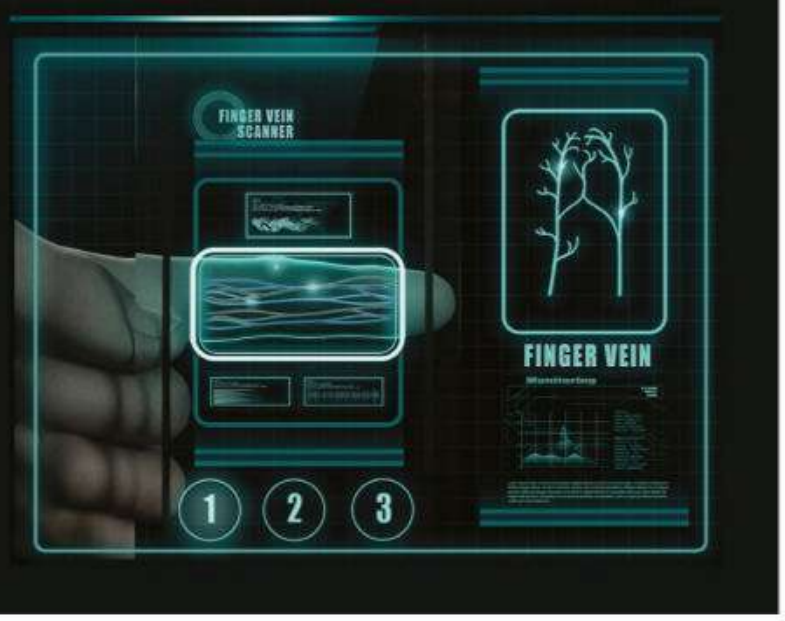
3 DIGITAL IMAGE
The light is focused through a lens before it hits the image sensor, creating the digital image for comparison.

5 VEINS
When infrared light passes through the skin, it illuminates the unique network of veins within.



6 CAMERA
An imaging sensor detects the infrared light that isn't absorbed by the veins and creates a detailed image.

4 INFRARED
An array of infrared LED bulbs emit light over the finger or the entire palm.



© Getty / Illustration by Nicholas Forder

FACIAL RECOGNITION

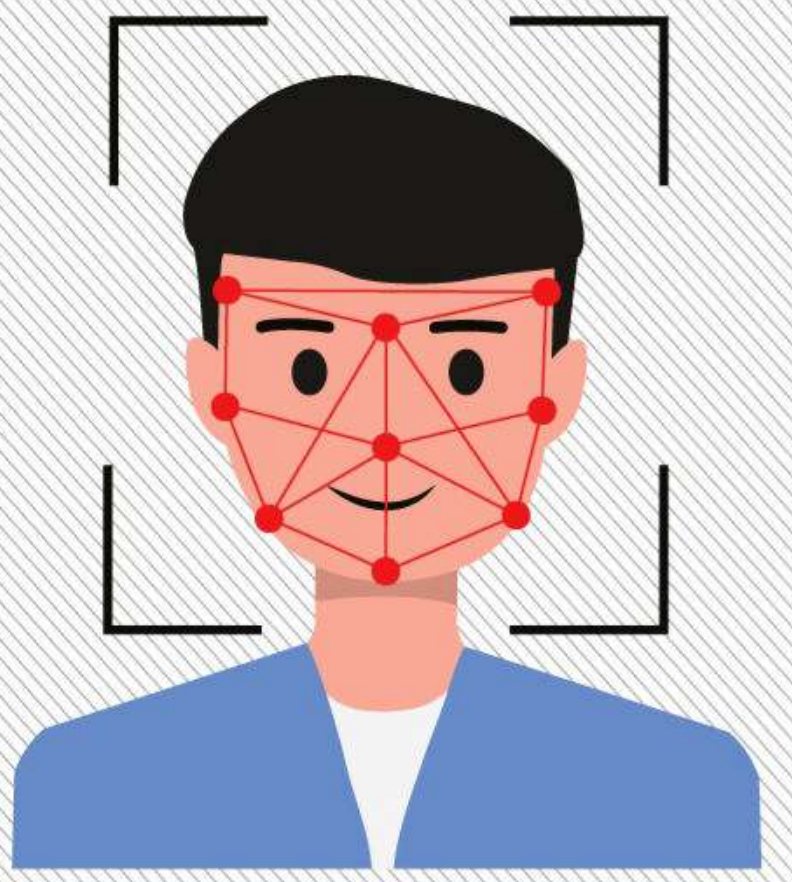
It's quickly becoming second nature for people to unlock their smartphone by simply looking in its direction. The concept of facial recognition dates back to the 1850s, when suspected and prosecuted criminals were photographed for records used to identify escapees. 170 years or so later and digital facial recognition has become a prominent way to accurately identify someone. Facial recognition works in the same way that our brain can recognise people based on the information it's fed by our eyes. Inside a pair of eyes, algorithms calculate different features on the face, such as the distance between the eyes, width of the nose and jaw length to build a 'faceprint'. The faceprint then acts as a template used to compare images or footage and conclude a match.

Facial biometrics aren't 100 per cent accurate all of the time. For example, facial recognition relies on comparing two images of a face to make a match. However, naturally our faces age and physically change over time. Some studies have shown that some recognition software can't cope when trying to match faces that might have developed wrinkles. In some cases, five years of ageing was enough to throw some software off. A person's race or ethnicity also appears to play a role in some algorithms' ability to recognise their faces. In 2018, researchers discovered that facial recognition software misclassified black women almost 35 per cent of the time.

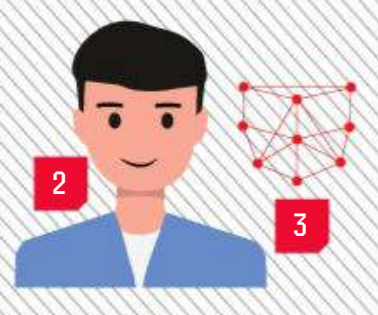
Facial recognition software creates a digital copy of your face as a reference

FINDING YOUR FACE

How facial recognition takes a selfie and decides if it's you in the image



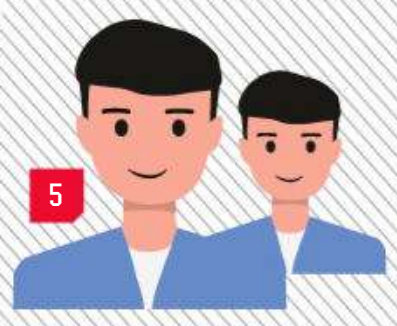
1 SNAPSHOT
A photograph or video is taken of the face as a reference image.



2 ANALYSIS
The geometry of the face is analysed, highlighting key features such as eye position and length of the face to create a unique facial signature.

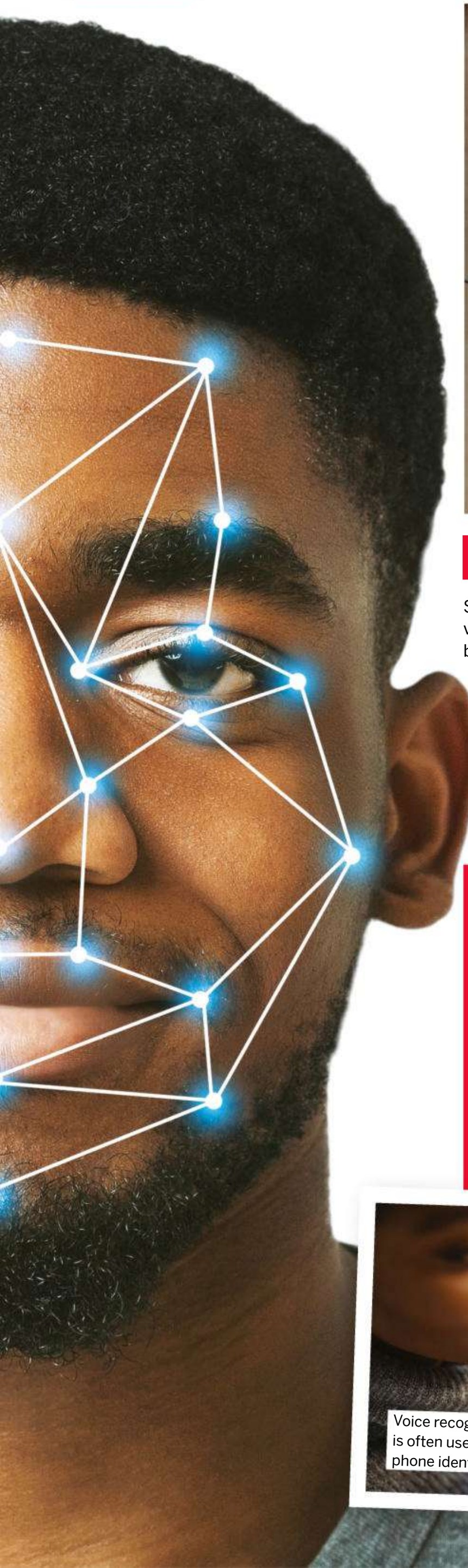
3 FACEPRINT
The facial recognition software creates a facial signature or faceprint that includes each of the measurements it's taken.

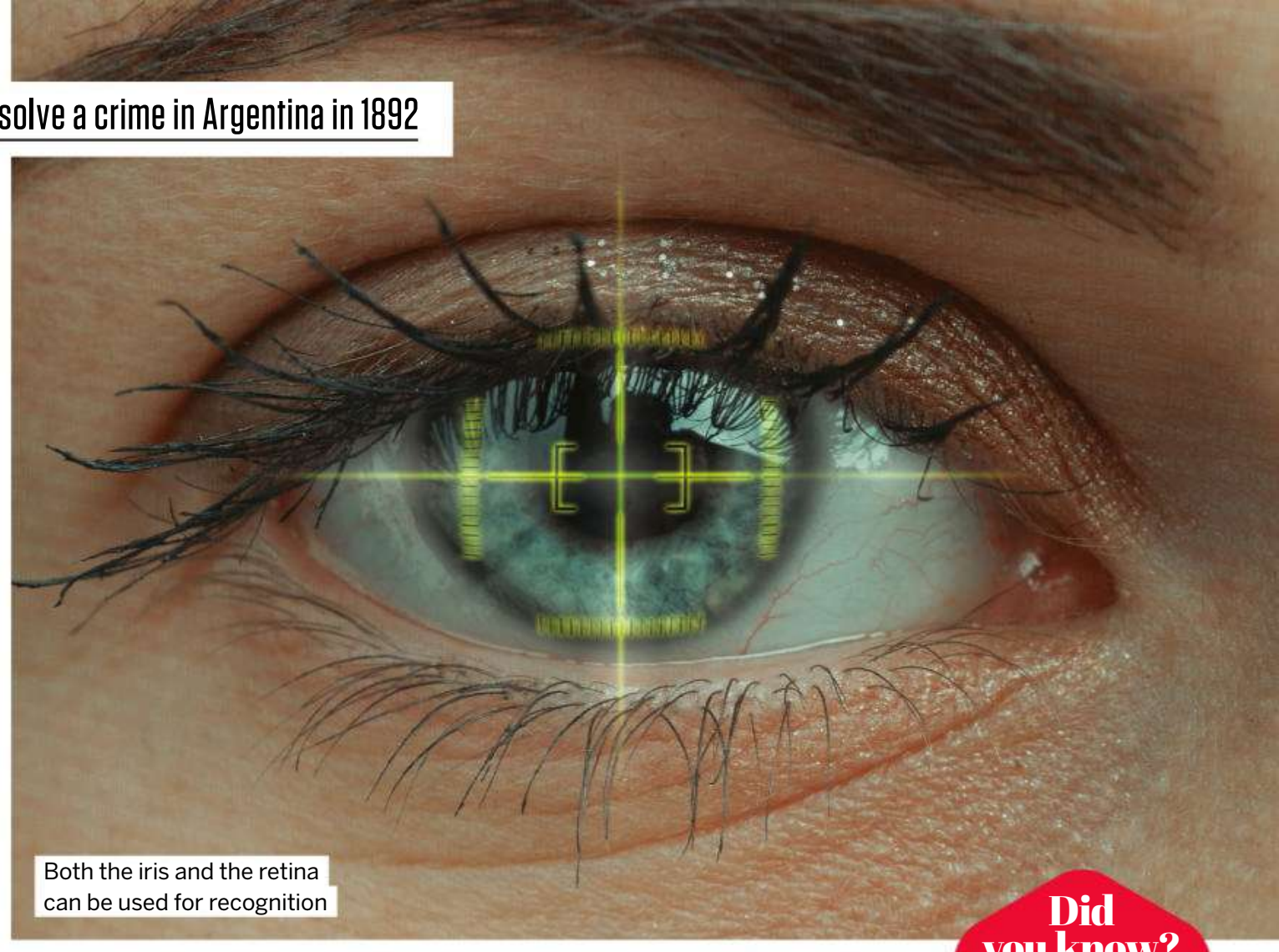
4 COMPARISON
The faceprint is then compared to either live image or video footage to match each of the points calculated.



5 IT'S A MATCH
If enough of the faceprint points match with the person using facial recognition, a match is determined.

DID YOU KNOW? Fingerprints were first used to solve a crime in Argentina in 1892





Both the iris and the retina can be used for recognition

RETINA RECOGNITION

Similar to the way we can be identified by the veins in our fingers, the blood vessels at the backs of our eyes can also reveal our true identity. By casting a beam of low-energy infrared light on the eye, the light passes through the lens and hits the network of capillaries at the back of the eye, called retinal veins. These veins absorb the infrared light and become illuminated, so much so that a camera can capture them. The vein images can then be run through a computer algorithm to match their orientation and position in the eye against a database for identification.

Retina recognition should not be confused with iris recognition, which uses infrared light to illuminate unique patterns and details in the eye's iris, the coloured tissue. These unique patterns are then captured by a camera. Images are then compared to a reference and a match is determined.

Did you know?

Retina recognition was invented in 1994

VOICE AUTHENTICATION

In the same way that fingerprints and facial features can be used to authenticate a person's identity, our speech is packed with unique markers for identification. Voice recognition software converts the sound of a voice into digital information. Also known as a voiceprint, the human voice is recorded and transformed through a biometric mathematical engine into what is known as a 'template'. This template is made up of distinctions in a person's voice, such as pitch, cadence and tone. During the process of authenticating a voice, the template and the speaker's voice are compared and a match is confirmed or denied.

But your voice isn't the only way to identify yourself using your mouth. Researchers from Kyushu University in Japan have developed sensors that can analyse the chemical compounds within our breath and identify where they came from. Working as an artificial nose, the olfactory sensor array can detect and measure 28 compounds released in a single breath. Using AI technology, a breath profile was constructed by six study participants. Over time the AI program could accurately identify each participant with 97.8 per cent accuracy in subsequent breath tests.

Voice recognition software is often used in over-the-phone identification

© Getty

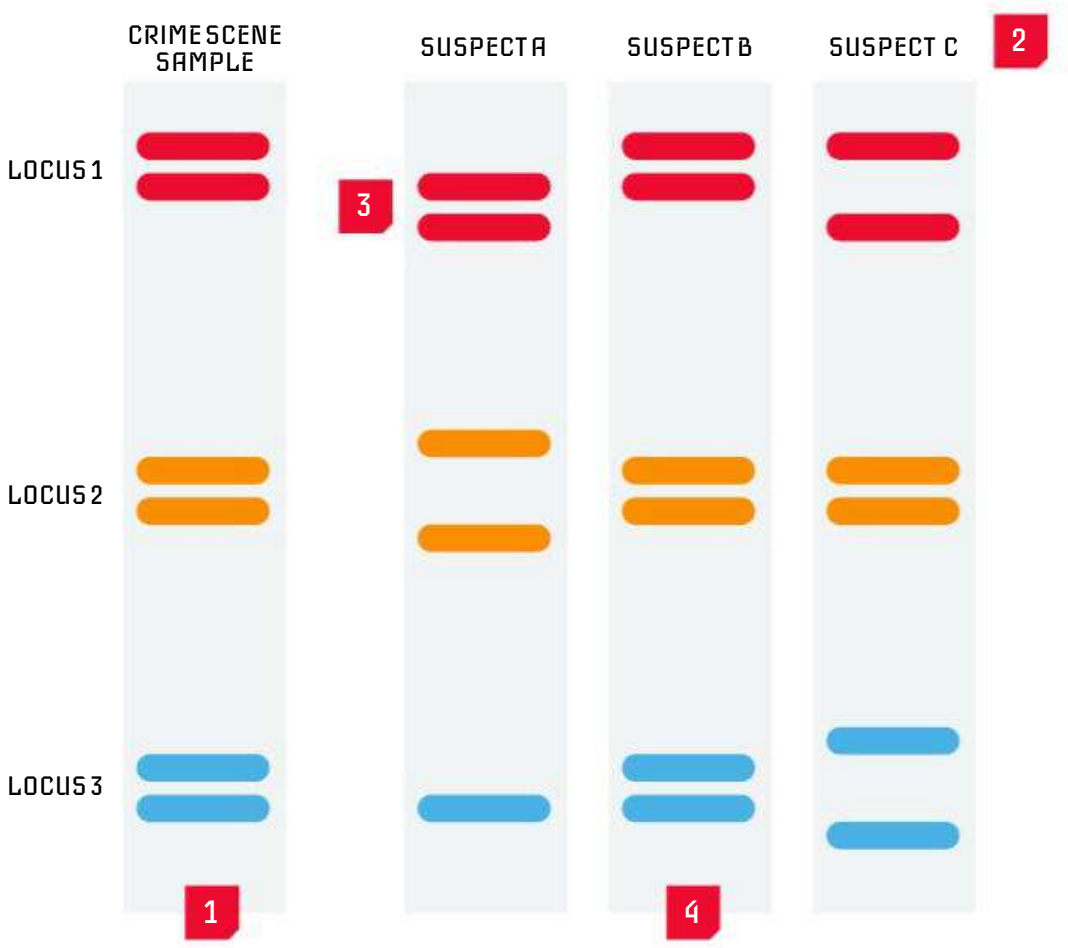
DNA PROFILING

As the blueprint of the human body, DNA offers the most accurate way to identify someone. 99.9 per cent of our genetic make-up is shared among humans, with the remaining 0.1 per cent revealing our unique inherited characteristics. The unique variations in our DNA are called polymorphisms. These are made up of simple repeating sequences of genetic information known as short tandem repeats (STRs). These don't code for any particular recognisable traits, but differ from person to person. By measuring the lengths and repetitions of STRs, scientists can accurately detect when two genetic samples match.

Some studies have explored the possibility of combining DNA recognition technology with other biometric methods. In scenarios where the origins of a DNA sample are in question, researchers have demonstrated the possibility of taking genetic information and reconstructing an image of a person based on it. Using artificial intelligence, researchers at the Centrum Wiskunde & Informatica in the Netherlands are developing software that uses DNA coding to reconstruct a person's face. The AI seeks to replicate facial appearance or characteristics, also known as phenotypic traits, that would be expected to form through natural embryonic development based on that person's genetic make-up. Much like how a sketch artist uses the information given by a witness to draw the suspect, the AI uses DNA to digitally paint a picture of the suspect for identification.

SPOT THE CRIMINAL

How forensic scientists compare DNA samples to discover the truth



1 CRIME SCENE SAMPLE
DNA evidence discovered at the scene of a crime is subjected to genetic testing.

2 SUSPECTS
Samples are put through a process called polymerase chain reaction that reveals the unique genetic segments.

3 SHORT TANDEM REPEAT SEQUENCES
Typically, ten STRs are identified for comparison between two samples.

4 A MATCH
A DNA sample that has identical STRs confirms a match and places a suspect at the crime scene.

DNA profiling allows forensic scientists to accurately identify possible criminals

REAL OR FAKE?

How do you know a fingerprint or voice is legitimate? As biometric technologies advance, so do fraudulent methods designed to deceive them. For example, in facial recognition, how does a piece of biometric software know the person it's trying to identify is real and not a copied image or a video of that person. To prevent such fraudulent activity, biometrics are equipped with systems called liveness detection. These systems are either referred to as active or passive systems. Active systems require someone to complete certain tasks, such as blinking or turning their head to prove their 'liveness', while passive systems don't require an action from a person and often rely on AI to analyse images to assess 'liveness'.

Did you know?

66 per cent of smartphones will have biometrics by 2024

How do you know when the person you're looking at is real?

DID YOU KNOW? Only a few non-humans have unique fingerprints, such as gorillas, chimps and koalas

BIOMETRIC USES

LAW ENFORCEMENT

Fingerprint scans, facial recognition and DNA have long been used by law enforcement to investigate crimes, either in searching for suspects through facial recognition or confirming the suspect's whereabouts through DNA evidence.

AIRPORT SECURITY

Biometric technology is becoming commonplace among security measures in places such as airports. Facial recognition is being used around the world to verify your identity against your passport when entering a country.

BANKING

Voice recognition software is more advanced in the financial sector. As a reliable method of identification that can be used over the phone, voiceprints can authenticate customers quickly when they call.

HEALTHCARE

Biometrics can open doors in the healthcare industry. Either as a way to access healthcare information remotely, over the phone or in moments of emergency, using a face, fingerprint or voice can allow secure and fast access to medical records.

COMMERCIAL

People are quickly ditching their wallets for smartphones as a way to pay for goods. Either with a glance at their phone's camera or a quick fingerprint scan, digital wallets such as Google Pay or Apple Pay are making it much easier to access our money.

© Getty

GOPRO HERO11 MINI TEARDOWN

The GoPro is designed to capture both the subject and their surroundings

Explore the technology of this action-capturing camera

WORDS **AILSA HARVEY**

For extreme sportspeople, daily vloggers and keen photographers, GoPros are neat little devices that can be used to capture scenes hands-free. They come with different mounts, allowing users to wear them on their heads, clothes and sporting equipment. All GoPro cameras need to be relatively small, but the GoPro HERO11 Mini has a width 20 millimetres smaller than the standard-sized GoPro HERO11. With dimensions of 5.3 by 5.2 by 3.8 centimetres, the camera is actually four millimetres thicker than the larger version and is the same height.

The camera comes with two built-in fixing rods, which extend from the device's main body. When unfolded, these rods can be used to mount the camera onto equipment like helmets, surfboards, camera stands or even the bottom of a skateboard. The combination of its compact design and mounting rods to increase attachment options helps content creators shoot from the most unique angles. And when making videos, recording can be started and stopped with the press of a single button. This makes the GoPro easy to use, especially when multitasking.

Editing videos can be a fun, yet time consuming chore after filming. With this GoPro model, some of the footage is compiled into highlight videos automatically and sent straight to your phone to be viewed. This feature is ideal for those who are keen to share their experiences soon after shooting. With this miniature camera, the user can create high-quality and stable footage. Its wide-angle camera means that the wearer's movements can be viewed as well as a large part of their surroundings. The HyperSmooth 5.0 filming technology of this model includes 'horizon lock', a feature that causes the camera to locate and maintain a fix on the horizon. As the camera twists and shakes, the horizon lock reduces distortion and mitigates shaky filming.

Without a screen, the GoPro HERO11 Mini is more square-shaped

WHERE'S THE SCREEN?

Being a smaller GoPro, the Mini model has no screen to view videos and photos. This might seem like a great loss if you are the kind of person who wants to view the footage instantly after recording. However, the screen is the weakest point on GoPro cameras, so what the GoPro HERO11 Mini loses in viewing ability, it gains in durability. Because GoPros are often worn on the body and used to record an activity from someone's point of view, seeing what image is in the camera's frame isn't always necessary. However, owners of this model can still check what their camera is seeing by using the 'GoPro Quik' smartphone application.

DID YOU KNOW? The GoPro HERO11 Mini can shoot 8x slow-motion videos at a resolution of 2704 by 1520

INSIDE THE COMPACT CAMERA

How the GoPro HERO11 Mini's packed insides form a high-quality recording device

1 FLEXIBLE CIRCUIT BOARD
This circuit board can bend slightly in order to fit neatly into the tight space.

2 SPEAKER
The speaker creates a beeping sound to alert the user that the camera has started recording.

3 MICROPHONE
A microphone faces the rear of the device to capture sound from this direction. Two more record sound from the front and side.

4 BATTERY
The camera's lithium-ion cell battery lasts 73 minutes when filming 5.3K resolution at 30 frames per second.

5 GOPRO GP2
This processor enables the capturing of images at high frame rates and with good stabilisation for shooting on the move.

6 MEMORY CARD
An efficient internal memory card has a storage capacity of eight gigabytes.

7 LENS
While this GoPro is smaller in size compared to the standard models, the lens size remains the same.

8 WATERPROOF CASING
The impact-resistant casing also waterproofs this camera to depths of up to ten metres.

Did you know?
The GoPro Mini is 13 per cent smaller than the standard model

Videos taken with the camera can be edited using the GoPro Quik app

© iFixit / Getty / Alamy

HISTORY

MACHINES OF WAR

Humankind has always excelled at crafting weapons of death, from ancient mechanised monstrosities through to the sleekest warfare tools of today

WORDS **ROB JONES**

Throughout history, humans have warred in the name of race, religion, colour and that oldest of ambitions: power. The creativity used to write amazing books, paint masterpieces, compose symphonies and produce inventions that have transformed the world forever has also been turned to the sphere of warfare. The mastery of physics, mathematics and engineering have been used to build increasingly refined machines of war.

No matter where the perceived threat has been located, be it on land, sea or in the air, humans have managed to build some sort of weapon to eradicate it. From colossal monolithic catapults capable of hurling bone-shattering boulders, through vast warships capable of levelling entire towns with a battery of cannon fire to missiles that can cross entire continents, our ingenious cruelty has known no bounds. War has shaped our civilisations, defined and redefined our human-made borders and even dictated our recorded history, with the truth of events almost always warped and corrupted by the victors, damaging our ability to learn from past mistakes.

Here we explore some of the most groundbreaking and notorious machines of war. Weapons that, despite their size and complexity, have gone down in history due to their infamy, arms that have been recorded due to their refined ability to wreak havok with an unsurpassed efficiency.

Did you know?

The 781-year Reconquista is the longest lasting war in history

DID YOU KNOW? The counterweight trebuchet is called the most powerful weapon of the Middle Ages

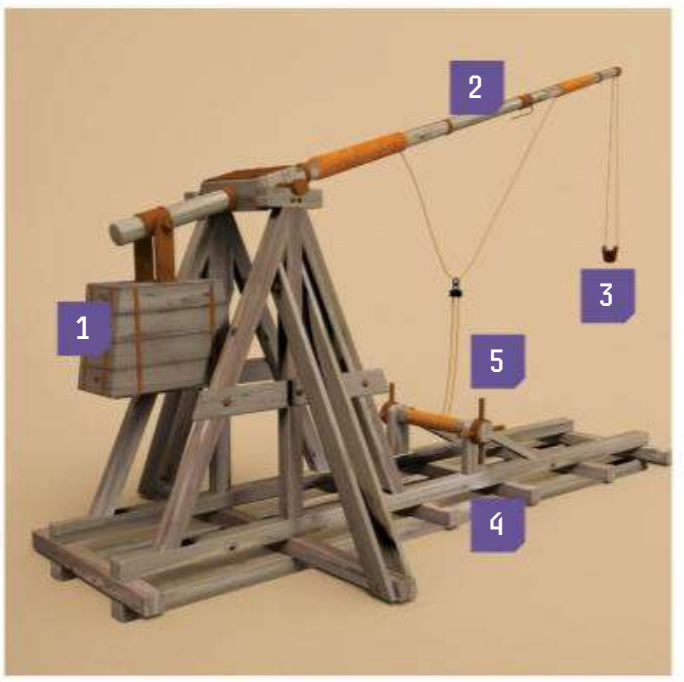
TREBUCHET 500 BCE

While humans had been killing each other for millennia prior to its invention, it was arguably only in the first millennium BCE that they started to bring serious engineering into the equation. Emerging out of China, the earliest traction trebuchets evolved from the ancient sling. Unlike the later and more famous counterweight trebuchets, they were small and were built so that only a few people were needed to operate them.

This type of primitive trebuchet worked by attaching a large sling to a long, wooden throwing arm, which itself was drawn back by humans pulling on long ropes and then actuated by a lever mechanism. The resultant sling action could propel weights of over 100 kilograms up to an impressive 60 metres and were useful as anti-infantry machines, crushing human and beast alike.

Despite the proliferation of the traction trebuchet, which spread throughout the East and then into the West in the late centuries BCE, it wasn't until the 11th century that the more advanced counterweight trebuchet was introduced. Unlike their forebears, these trebuchets were far larger, needed huge teams of soldiers to operate and were capable of throwing massive weights incredible distances. This was due to their novel counterweight-propulsion mechanism, which utilised gravity to rotate the throwing arm.

The consequence of the larger scale and more refined throwing mechanism meant that missiles weighing over 300 kilograms could be propelled up to 300 metres. Now it wasn't just humans and animals that needed to fear the wrath of the trebuchet, but the inhabitants of castles and forts too, with their supposedly impregnable walls giving little protection from the rain of rocks, flaming pyres and diseased animal carcasses hurtling towards them.



SIEGE BREAKER

EFFICIENCY ●●○○○

COLLATERAL DAMAGE ●●●○○

SHOCK FACTOR ●●●○○

ENGINEERING GENIUS ●●○○○

3 SLING
The trebuchet's ammunition is held by the sling, a reinforced leather, fabric and rope strapping attached to the end of the throwing arm. The sling is propelled forwards by the throwing arm to release its contents.

2 THROWING ARM
A long wooden strut that pivots within the trebuchet's framework, the throwing arm is responsible for propelling the device's ammunition.

5 PROJECTILE GUIDE
Situated on the base frame, the projectile guide is a crucial component on the trebuchet, as even the smallest error in alignment at the firing end can lead to the projectile widely missing its mark.

1 COUNTERWEIGHT
Ranging from a simple boulder though to a purpose-built weight-carrying container, the trebuchet's counterweight is the component that grants it its enormous power, utilising gravity's effect on it to rotate the throwing arm rapidly.

4 BASE AND FRAME
Due to the weight of the missiles thrown, a large, flat base is required. This base is often affixed to the ground by braces to eradicate any lateral movement while firing. A support frame is also necessary to prevent stress fracturing.

BALLISTA
400 BCE

BRUTAL SNIPER

EFFICIENCY ●●●○○

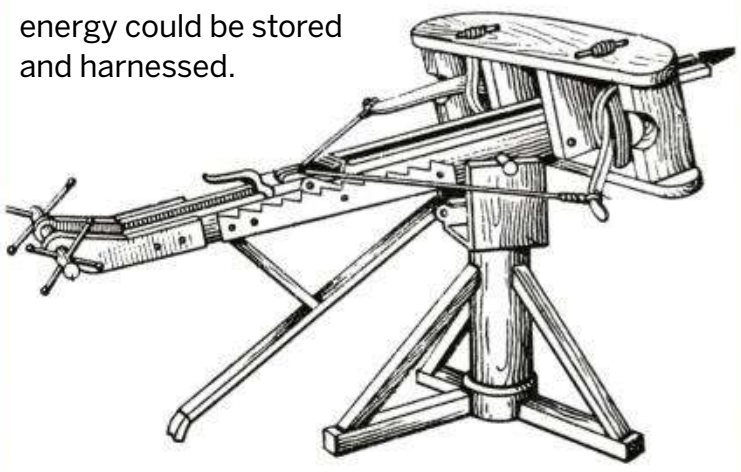
COLLATERAL DAMAGE ●●○○○

SHOCK FACTOR ●●●●○

ENGINEERING GENIUS ●●○○○

The earliest form is thought to have been developed for the Greek tyrant Dionysius of Syracuse in around 400 BCE. The ballista was a weapon designed to throw 26-kilogram metal-tipped lances at high velocity towards – and through – humans. However, the ballista's brutal mechanism was not the only reason it was so feared on the battlefield – it was its excellent range and accuracy.

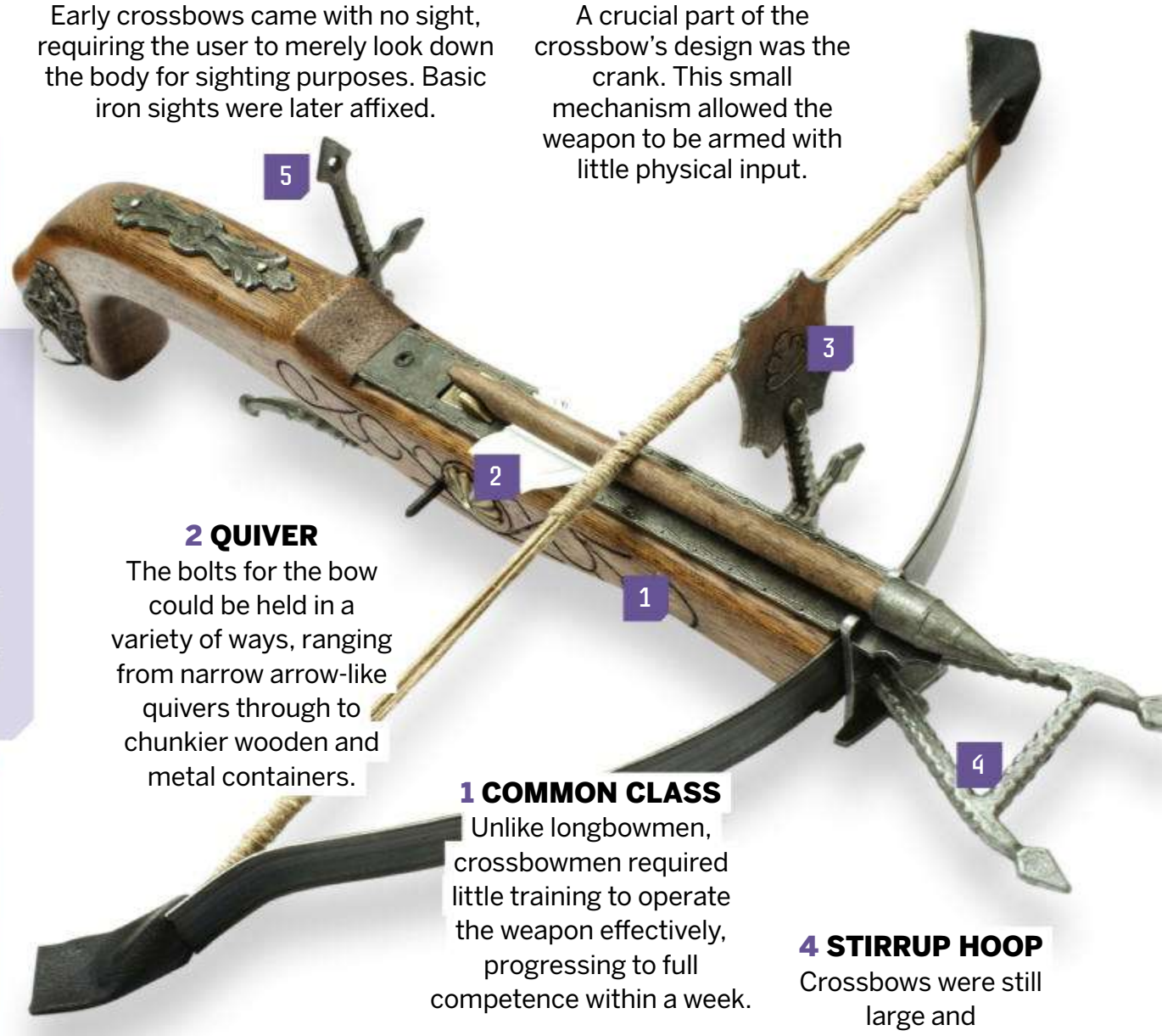
The ballista was the first true sniper weapon, with the largest variants capable of hitting single targets from over 450 metres away. Historical records from Roman times indicate that skilled operators could pick off enemy archers even with them in an advantageous position, such as on battlements. The ballista was so effective thanks to its utilisation of the torsion spring, which had been invented in the last decades of ancient Greece. Torsion springs were wrapped around the weapon's bow arms, with the arms in turn attached to the lance-throwing bowstring. As the torsion springs were winch-twisted by the weapon's operators, extreme amounts of energy could be stored and harnessed.



An illustration of an ancient ballista

5 SIGHT
Early crossbows came with no sight, requiring the user to merely look down the body for sighting purposes. Basic iron sights were later affixed.

3 CRANK
A crucial part of the crossbow's design was the crank. This small mechanism allowed the weapon to be armed with little physical input.



2 QUIVER
The bolts for the bow could be held in a variety of ways, ranging from narrow arrow-like quivers through to chunkier wooden and metal containers.

1 COMMON CLASS
Unlike longbowmen, crossbowmen required little training to operate the weapon effectively, progressing to full competence within a week.

4 STIRRUP HOOP
Crossbows were still large and cumbersome weapons to handle, so many designs were equipped with a foot stirrup.

CROSSBOW
200 BCE

By taking the principles and engineering of the ballista and then shrinking it, this refined machine placed the power of life and death in more hands than ever before. Cheap to build and easy to operate, the crossbow changed the entire culture and tactics of ranged combat. Prior to its invention the bow and arrow had been the only form of handheld long-range weaponry, and they required considerable skill, strength and training to fire. However, the crossbow could be placed in anyone's hands and fired with little effort, transforming even the weakest individuals into expert marksmen.

The crossbow spread from East Asia into the West in the early centuries of the common era, becoming established as the primary form of ranged weaponry in numerous European armies by the 12th century. The result was that many established military roles were rendered obsolete, such as the heavily armoured knight class who were vulnerable to the high-velocity crossbow bolts and thus no longer as useful.

BOW KILLER

EFFICIENCY ●●●●○

COLLATERAL DAMAGE ●○○○○

SHOCK FACTOR ●●●○○

ENGINEERING GENIUS ●●●○○

HISTORY'S OTHER KILLING MACHINES

30,000 BCE
SHORTBOW
After the spear and dart, the oldest weapon to be created by humankind was the bow and arrow.

2000 BCE
SPOKE-WHEELED CHARIOT
These battle taxis could cut down men and animals as well as provide mobile platforms.

1000 BCE
BATTERING RAM
Developed in ancient Assyria, the battering ram went on to be a key machine of war for any army.

900 BCE
SIEGE TOWER
A large, armoured, mobile tower in which soldiers could climb up to the level of a city's walls and surmount them.

673 CE
GREEK FIRE
A mix of chemical components including pine resin, naphtha, sulphur and nitre were used to make an incendiary weapon.

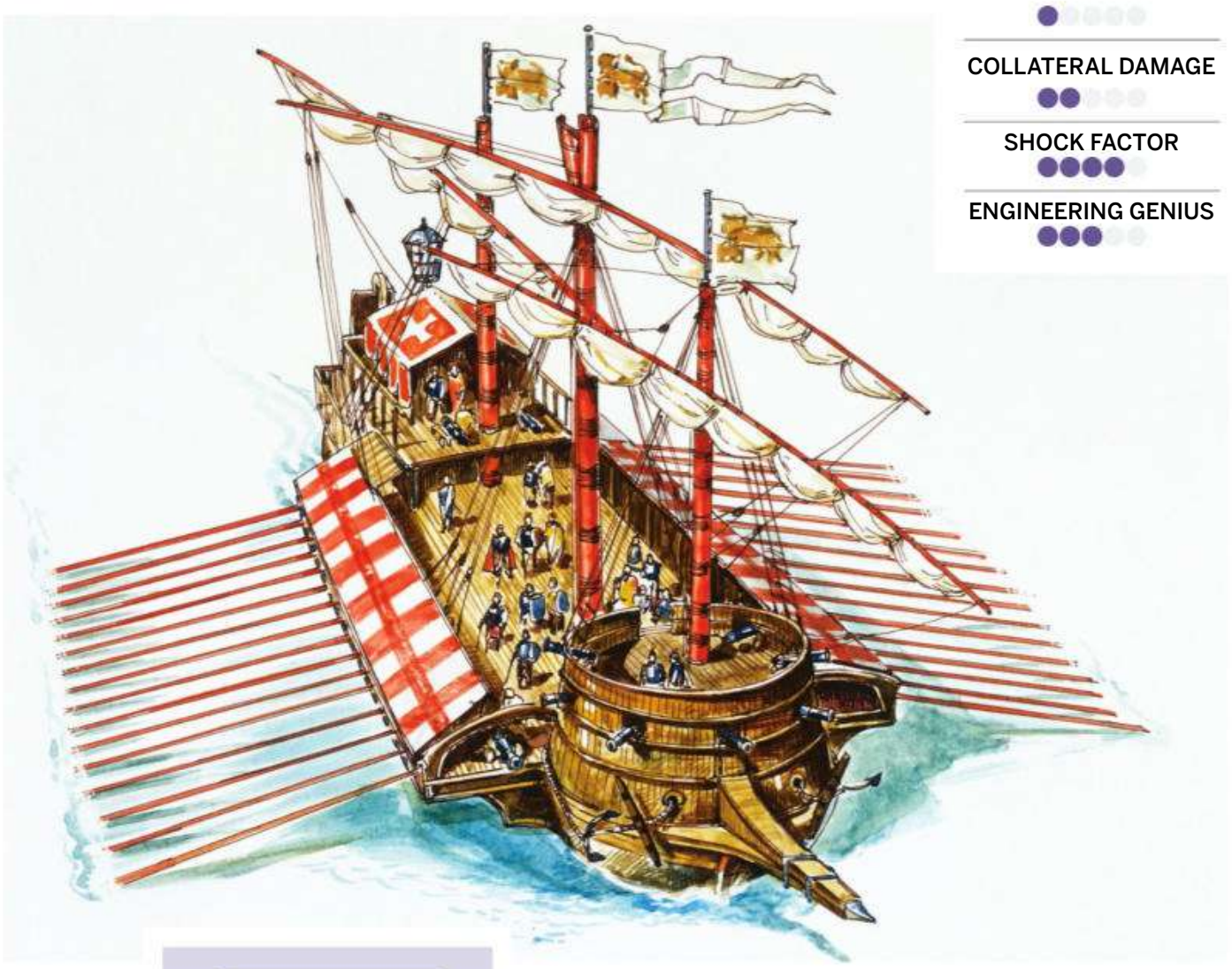
DID YOU KNOW? Medieval crossbows could be fired up to around 320 metres

WAR GALLEY 100 BCE

The war galley became the backbone of almost all navies around the world following its introduction, reaching peak usage in the 15th century. Its popularity stemmed from its excellent suitability to pre-cannon naval warfare, with its long, narrow hull making it responsive at sea, as well as providing excellent straight-line speed under oar, allowing its crew to cross bodies of water more rapidly than before.

From the ancient Greeks and Assyrians onward, the galley was rarely equipped with any sort of weaponry, with its only form of direct attack being to ram the opposition. Another popular tactic was to sacrifice a vessel and turn it into a fireship. Despite the lack of weapons, the galley was feared, as it could quickly drop off 50 or more heavily armed soldiers in enemy territory or chase down rivals on the water like no other.

In the last decades of its widespread use, cannons were introduced to the galley with limited success. Due to the vessel's design – with a narrow hull and oarsmen at either side – the cannons had to be placed at the bow facing forward, limiting the firing arc and gun placements.



DEATH ON THE WAVES

EFFICIENCY ●○○○○

COLLATERAL DAMAGE ●●○○○

SHOCK FACTOR ●●●●○

ENGINEERING GENIUS ●●●○○

CANNON 1100

First developed by the ancient Chinese, the cannon evolved from the fire lance, gunpowder-filled tubes that could be sent flying at an enemy. As the cannon spread to the West, it evolved into the larger metal-barrelled weapon we know today. These cannons fired cannonballs, as well as chunks of shrapnel. An early example of the Western cannon is the pot-de-fer, or iron pot, a primitive cannon made with an iron barrel. This was used by the French and the English during the Hundred Years' War, superseded by more refined variants of various sizes. Soon, cannons of different sizes were in operation, ranging from small, cart-mounted mobile artillery units right through to immense monsters that required a team of 200 men to operate effectively and more than 70 oxen to transport.

FIRE AND IRON

EFFICIENCY ●●●○○

COLLATERAL DAMAGE ●●●○○

SHOCK FACTOR ●●●○○

ENGINEERING GENIUS ●●○○○

1000 CE
GUN
The first identified gun originated in China and consisted of a bamboo tube filled with gunpowder and a spear. When ignited, the spear would be propelled.

1277
LAND MINE
The first land mines emerged out of the 13th-century Chinese Song dynasty. The devices were used with tripwires to catch unsuspecting enemies unawares.

1450
ARQUEBUS
A forerunner to the musket and the rifle, the arquebus was an early muzzle-loading, smooth-bore firearm. It was lighter and much less accurate than the musket.

1453
MORTAR
An evolution of the straight cannon, the mortar introduced explosive ammunition to the battlefield, with the machine hurling gunpowder-filled bombs at the enemy.

RIFLE 1800

The rifle took the smooth-bore musket and made it even more lethal. This lethal touch was added thanks to an ingenious modification to the barrel of the weapon. By scoring a helical groove, referred to as the rifling, into the barrel's walls, as the weapon's projectile – such as a bullet – passed through it, the barrel would make it spin, significantly increasing the weapon's range and accuracy.

The first rifles were introduced in the Napoleonic Wars, with the British arming soldiers with the new weapon. After initial problems with the rifle, such as difficulty in loading, it evolved to include breech-loading, allowing for bullets to be quickly inserted and fired. By the close of the 19th century, revolving rifles, repeating cartridge rifles and many other deadly rifles had been introduced.

DEATH IN A SPIN

EFFICIENCY ●●●●○

COLLATERAL DAMAGE ●○○○○

SHOCK FACTOR ●●●○○

ENGINEERING GENIUS ●●●●○

MACHINE GUN 1860

Of these first automatic machines, the Gatling gun was the deadliest, with its six barrels capable of firing hundreds of bullets per minute. Within years of its introduction, Gatling guns were in production that had theoretical rates of fire of over 1,200 rounds per minute.

The Gatling gun was soon followed by a conveyor belt of more refined and deadly machines. The handheld machine gun was created, as well as increasingly mobile iterations of the weapon that could be deployed on the battlefield with unsurpassed rapidity or mounted to ships, tanks and other military vehicles with consummate ease.

1,200 RPM

EFFICIENCY ●●●○○

COLLATERAL DAMAGE ●●○○○

SHOCK FACTOR ●●●●○

ENGINEERING GENIUS ●●●○○

U-BOAT 1903

A stealth weapon utilised by Germany during both world wars, the U-boat was an armed submarine capable of different roles – a fearsome hunter-killer, chasing down Allied vessels and sinking them with torpedoes, and as a raider, disrupting supply lines and enemy convoys. Due to their stealth ability, as well as the fact that they operated in groups referred to as 'wolf packs', the U-boat became infamous for its ability to sink even the biggest military warships while remaining undetected and unharmed. It was only when a variety of countermeasures were later developed, such as depth charges and active sonar, that the tide began to be turned on these wolves of the sea, with the Allied forces working in unison to take them down.

THE DEADLY WOLF PACK

EFFICIENCY ●●●○○

COLLATERAL DAMAGE ●●●○○

SHOCK FACTOR ●●●●●

ENGINEERING GENIUS ●●●●○

1550
MUSKET
A heavier, more refined evolution of the arquebus, the musket allowed its user to fire bullets at high velocity at the enemy.

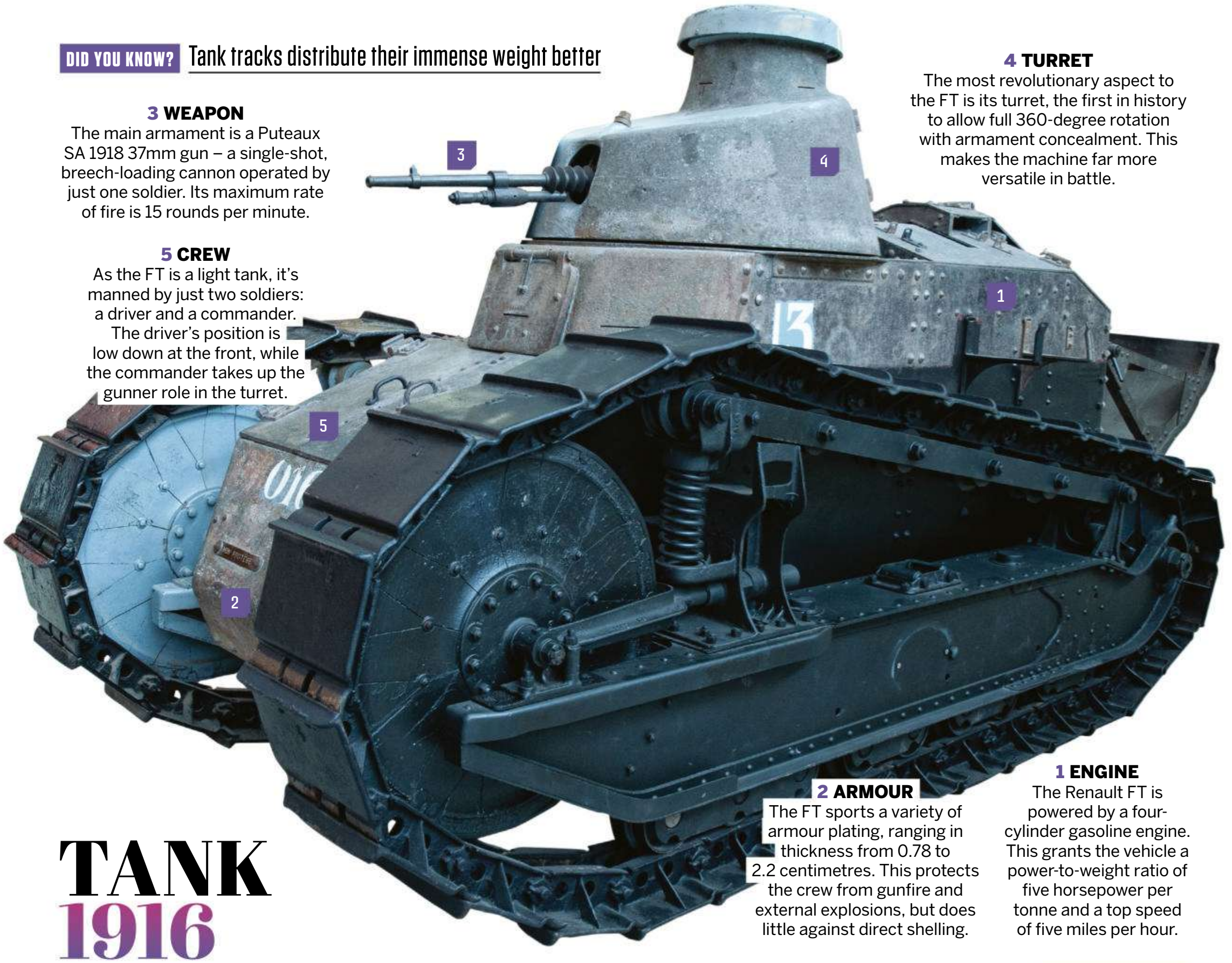
1866
TORPEDO
The first modern torpedo was the Whitehead torpedo of 1866, a self-propelled underwater weapon with a warhead of 53.5 kilograms of nitrocellulose.

1901
FLAMETHROWER
The modern flamethrower was invented by Germany's Richard Fiedler in 1901. The machine, which was single-shot, projected a jet of fire over 18 metres.

1915
FRAGMENTATION GRENADE
The first modern fragmentation grenade was the Mills bomb, an explosive-filled steel canister fitted with a triggering pin.

1942
NAPALM BOMB
A devastating mixture of petroleum and a gelling agent that sticks to human skin and causes severe burns when ignited.

DID YOU KNOW? Tank tracks distribute their immense weight better



3 WEAPON
The main armament is a Puteaux SA 1918 37mm gun – a single-shot, breech-loading cannon operated by just one soldier. Its maximum rate of fire is 15 rounds per minute.

5 CREW
As the FT is a light tank, it's manned by just two soldiers: a driver and a commander. The driver's position is low down at the front, while the commander takes up the gunner role in the turret.

4 TURRET
The most revolutionary aspect to the FT is its turret, the first in history to allow full 360-degree rotation with armament concealment. This makes the machine far more versatile in battle.

2 ARMOUR
The FT sports a variety of armour plating, ranging in thickness from 0.78 to 2.2 centimetres. This protects the crew from gunfire and external explosions, but does little against direct shelling.

1 ENGINE
The Renault FT is powered by a four-cylinder gasoline engine. This grants the vehicle a power-to-weight ratio of five horsepower per tonne and a top speed of five miles per hour.

TANK 1916

Weighing several tonnes, armed with shell-slinging cannons and protected with thick metal plating, these tracked titans not only changed warfare forever, but struck fear into the hearts of men, no matter their allegiance or nationality. The tank was born out of the suicidal stalemate of World War I, with the Allies desperate to create a machine of war capable of breaking the limbo malaise of trench warfare. The British were the first to field a tank in 1916, the Mark I, but this machine and its immediate successors were renowned for mechanical unreliability, granting little real edge in combat aside from the fear factor it struck when operational.

By World War II, the tank had developed into a key unit in any army, capable of literally steamrolling the enemy under their weighty tracks. Men could be crushed and shot, buildings and vehicles could be demolished and despoiled and enemy lines could be stormed with ease. The common use of the tank would see new military tactics implemented, such as Germany's Blitzkrieg 'lightning war' that saw much of Europe taken within a series of short, brutal, tank-led campaigns.

ARMOURED BEASTS

EFFICIENCY ●●●○○
COLLATERAL DAMAGE ●●●●○
SHOCK FACTOR ●●●●●
ENGINEERING GENIUS ●●●○○

1944
HELICOPTER
The first mass-produced military helicopter was the Sikorsky R-4. This innovative war machine was capable of flying at 75 miles per hour.

1945
ATOMIC BOMB
The Manhattan Project produced the world's first atomic bomb. The weapons were then dropped on Hiroshima and Nagasaki in Japan.

1965
POWERED EXOSKELETON
These machines allow soldiers to lift and carry far more when in the field.

1974
TASER
A nonlethal weapon used to neutralise foes by electrical current-induced neuromuscular incapacitation, tasers are often used by police.

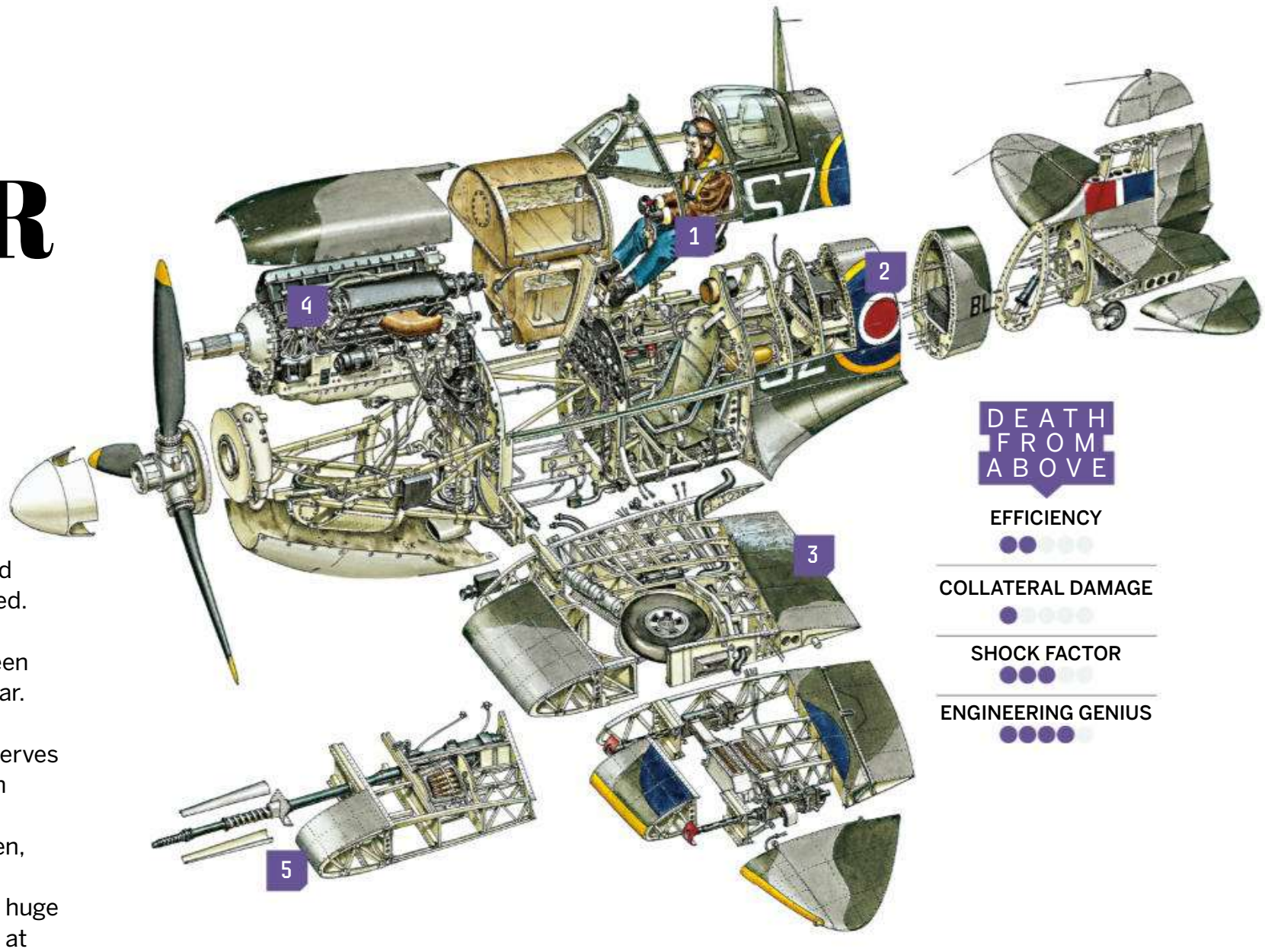
2014
UAV
While unmanned aerial vehicles have been in production for several decades, their usage today is greater than ever before.

FIGHTER PLANE 1914

Before the 20th century, humans had mastered ways to kill on sea and on land, but the air remained unconquered. That all changed at the outbreak of World War I, when the fighter plane was invented. Within years of the Wright brothers first taking to the skies, the aeroplane had been converted into a fearsome machine of war.

Equipped with braces of high-calibre machine guns and piloted by men with nerves of steel, these new fighters specialised in ripping enemies apart in intense aerial dogfights. The most famous of these men, such as the Red Baron, utilised these amazing new killing machines to rack up huge body counts, with rivals outmanoeuvred at high speed and then blown away in a hail of high-calibre rounds.

Fighters would continue to be developed right through the interwar period, leading to world-famous aircraft such as the Supermarine Spitfire and Messerschmitt Bf 109 to elevate the art of human-on-human aerial combat to an even higher level. Indeed, the new need by humans to fight in the air produced over 20,000 Spitfires during its service lifetime, with the aircraft prized for its prowess and maneuverability. The latter was aided by its powerful armament of twin 20mm Hispano Mark II cannons and four-gang of .303 Browning Mark II machine guns.



DEATH FROM ABOVE

EFFICIENCY

COLLATERAL DAMAGE

SHOCK FACTOR

ENGINEERING GENIUS

1 COCKPIT
The fully enclosed and streamlined cockpit grants its pilot good viewing angles when in control of the fighter – a crucial factor in aerial dogfights.

2 FUSELAGE
The Spitfire's airframe is incredibly advanced for its time, with a semi-monocoque duralumin fuselage made up from 19 smaller skeletal sections that begin immediately behind the propeller.

3 WINGS
The Spitfire is installed with revolutionary elliptical wings that not only have the thinnest possible cross-section of any contemporary, but also excellent speed and handling characteristics.

4 POWERPLANT
A beastly Rolls-Royce Merlin 45 supercharged V12 engine capable of a whopping 1,470 horsepower grants the Spitfire Vb an excellent top speed of 370 miles per hour and a rapid rate of climb of 13.2 metres per second.

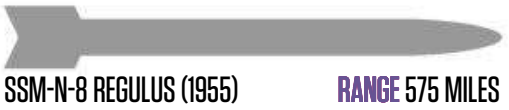
5 WEAPONS
The Spitfire's primary weapons are twin Hispano Mark II cannons capable of throwing out 60 high-calibre rounds per minute. Four Browning Mark II machine guns are also included.

ROCKET 1933

If war had become increasingly detached thanks to the invention of the tank and aeroplane, then with the invention of rockets it entered a truly modern age. The Germans began developing rocket technology in the 1930s, and the first of their so-called 'A' rockets flew in 1933. These rockets developed into the 'V' series and saw real success with the V-2 (Vengeance Weapon 2) rocket, the world's first long-range ballistic missile. The V-2 could deliver an explosive warhead capable of levelling entire buildings, killing masses of people and disrupting enemy installations. In the last year of World War II, over 9,000 soldiers and civilians were killed by deadly V-2 blasts.

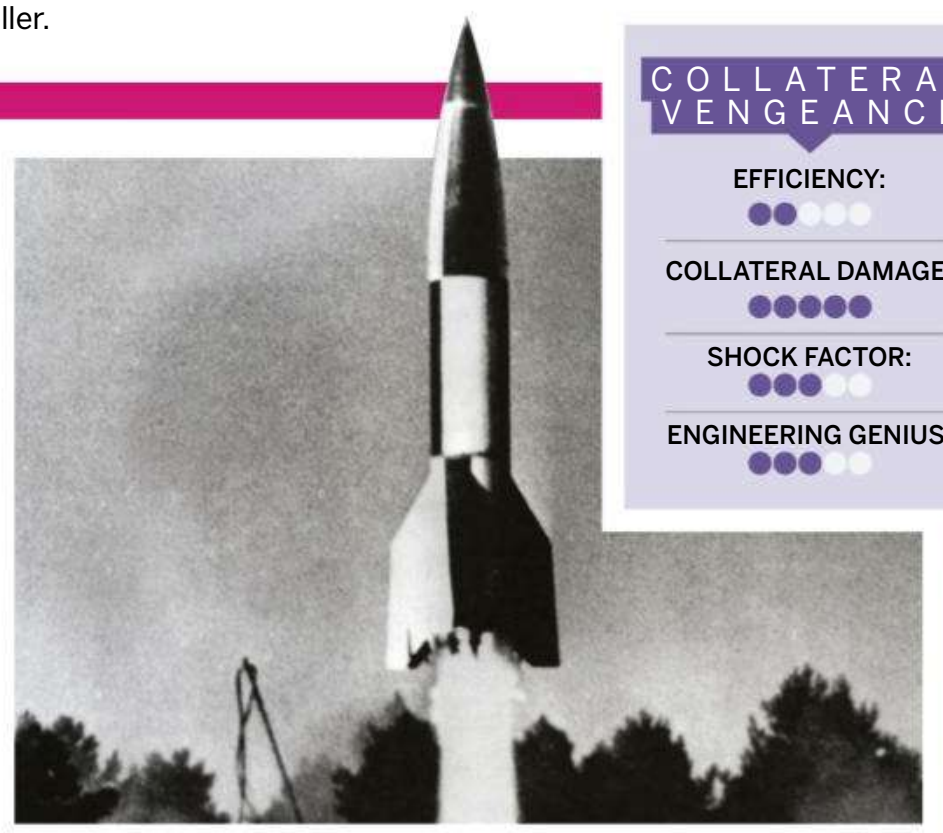
GUIDED MISSILE FAST FACTS

V-2 (1944) RANGE 200 MILES



SSM-N-8 REGULUS (1955) RANGE 575 MILES

TOMAHAWK (1983) RANGE 1,550 MILES



The V-2 introduced a new, terrifying dimension to warfare

COLLATERAL VENGEANCE

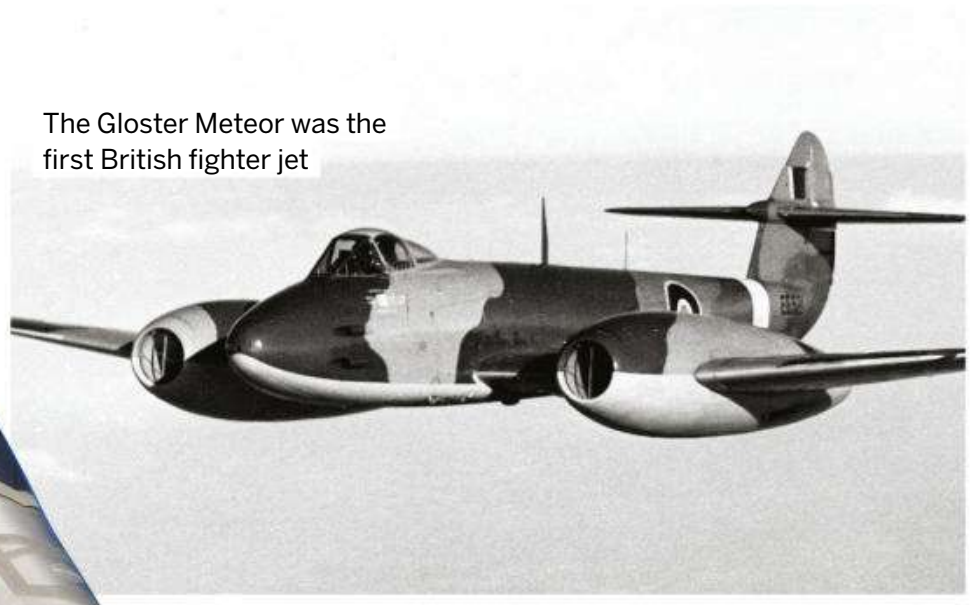
EFFICIENCY:

COLLATERAL DAMAGE:

SHOCK FACTOR:

ENGINEERING GENIUS:

DID YOU KNOW? The Wright Flyer, the first aeroplane, took off in 1903



The Gloster Meteor was the first British fighter jet

Fighter jets are a prime example of the rapid advancement of war machines

21ST-CENTURY KILLER

EFFICIENCY ●●●○○

COLLATERAL DAMAGE ●●●●○

SHOCK FACTOR ●●●○○

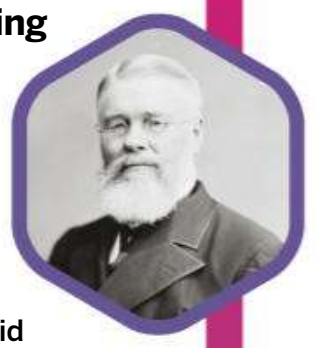
ENGINEERING GENIUS ●●●●●

FIGHTER JET 1942

Today, Earth's most advanced machine of war is the F-35 Lightning II, a multi-role jet fighter that costs over £185 million ($230 million) to buy and operate. The machine is the combined result of over 70 years of advancement in the jet fighter field. From the day the Messerschmitt Me 262A took to the skies in 1942, the jet fighter class of aircraft has become the world's most high-tech killer, allowing its pilot to obliterate enemies with a range of advanced smart munitions.

The F-35, fitted with its array of six external wing pylons and brace of four internal pylons, grants the aircraft a combined weapons payload of 8,100 kilograms. This allows it to carry a range of air-to-air missiles, such as the AIM-120 AMRAAM and AIM-9X Sidewinder, air-to-surface missiles such as the AGM-158 JASSM as well as anti-ship missiles. A wide variety of conventional bombs can be carried and released, such as the Paveway series of laser-guided bombs and Mk-20 Rockeye II cluster bomb. Just in case that arsenal isn't quite enough, the F-35 can also be strapped with the world-ending B61-12 nuclear bomb, which can deliver a variable yield of up to 340 kilotonnes. This is currently the most complex machine of war on the planet, but it surely won't be long until it is superseded by new inventions such as drones, which don't even need to be piloted, instead controlled from thousands of miles away.

THREE MEN OF WAR



Richard Jordan Gatling
1818 to 1903
Gatling gun

American inventor Richard Gatling became famous during his lifetime for his invention of the Gatling gun, a machine of war that he said would "enable one man to do as much battle duty as a hundred [and] supersede the necessity of large armies." The Gatling gun certainly didn't reduce the size of armies, or cease warfare, but it did lead the world into the machine gun age, with a series of his and rivals' automatic cannons swiftly following suit.

Mikhail Kalashnikov
1919 to 2013
AK-47 assault rifle

The designer of the most widely used assault rifle of all time, Kalashnikov was one of Russia's most decorated men, receiving the Stalin Prize, Lenin Prize, USSR State Prize and Hero of Socialist Labour Prize for his invention of the AK-47. Despite Kalashnikov's belief that his rifle was designed as "a weapon of defence, not a weapon of offense", the AK-47 has been used in most warfare over the past 60 years, with over 70 million rifles in circulation.

Reginald Mitchell
1895 to 1937
Supermarine Spitfire

A celebrated aeronautical engineer, Mitchell was responsible for designing the Type 300, an all-metal monoplane that would be transformed into the iconic Spitfire. Mitchell's machine of war proved to be incredibly adept at killing, and over 22,000 Spitfires were built. Speaking of the name the RAF chose for his fighter, Mitchell reportedly stated: "Spitfire was just the sort of bloody silly name they would choose."

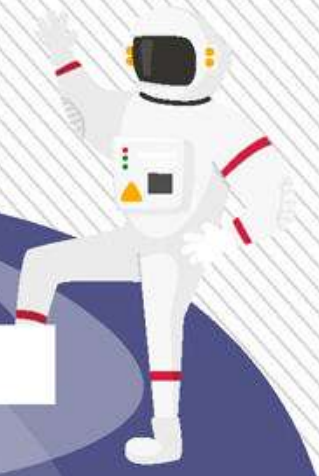
© Alamy / Getty

SCIENCE

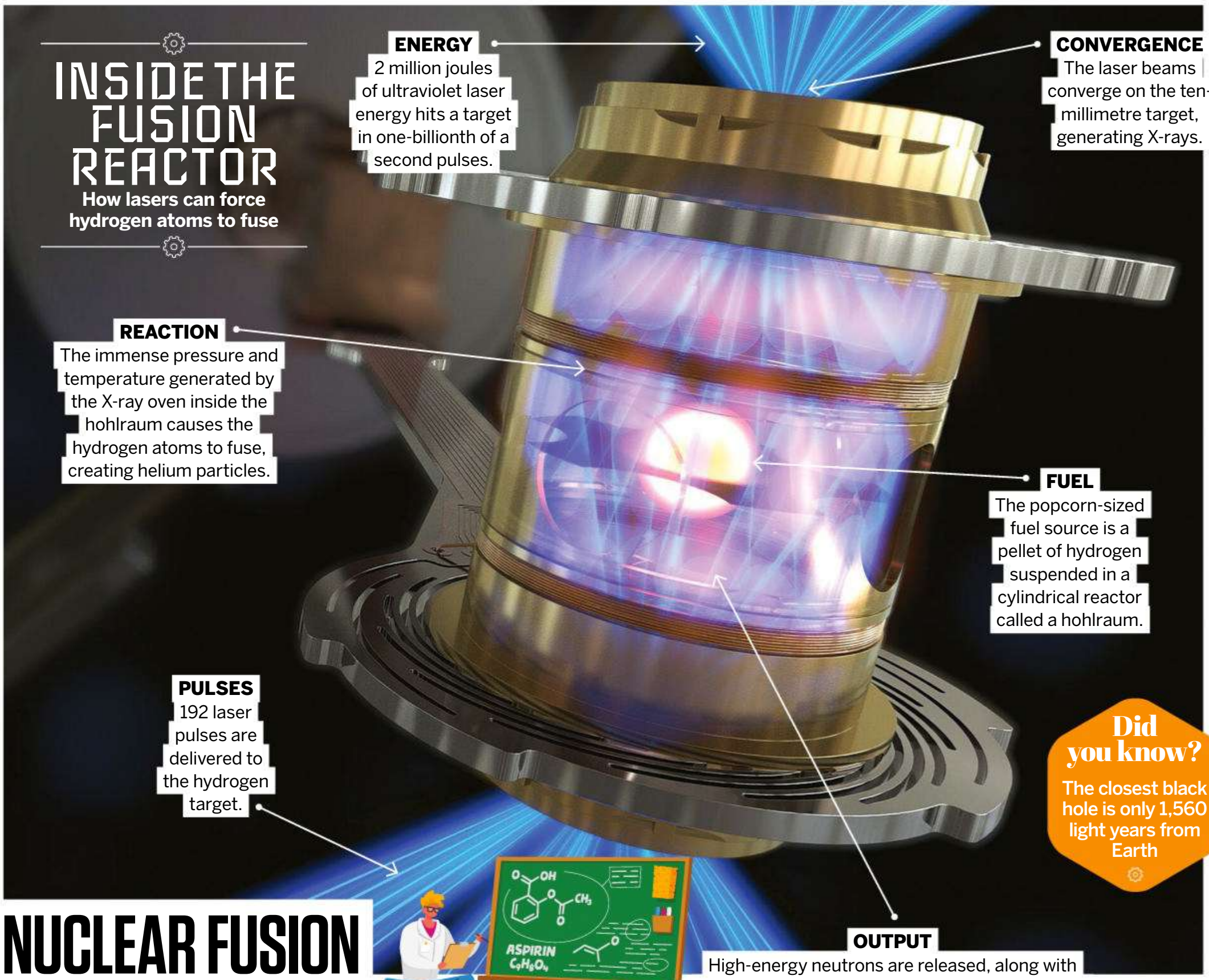
BIGGEST SCIENTIFIC BREAKTHROUGHS

Discover the most notable scientific discoveries, technological advancements and medical milestones of the past year

WORDS SCOTT DUTFIELD



DID YOU KNOW? In 2022, the first known surgical operation was discovered – a leg amputation carried out 31,000 years ago


INSIDE THE FUSION REACTOR
How lasers can force hydrogen atoms to fuse
ENERGY
2 million joules of ultraviolet laser energy hits a target in one-billionth of a second pulses.
CONVERGENCE
The laser beams converge on the ten-millimetre target, generating X-rays.
REACTION
The immense pressure and temperature generated by the X-ray oven inside the hohlraum causes the hydrogen atoms to fuse, creating helium particles.
FUEL
The popcorn-sized fuel source is a pellet of hydrogen suspended in a cylindrical reactor called a hohlraum.
PULSES
192 laser pulses are delivered to the hydrogen target.
OUTPUT
High-energy neutrons are released, along with other forms of energy, which equal or exceed the energy needed to create the reaction.
ASPIRIN
$C_9H_8O_4$

Did you know?

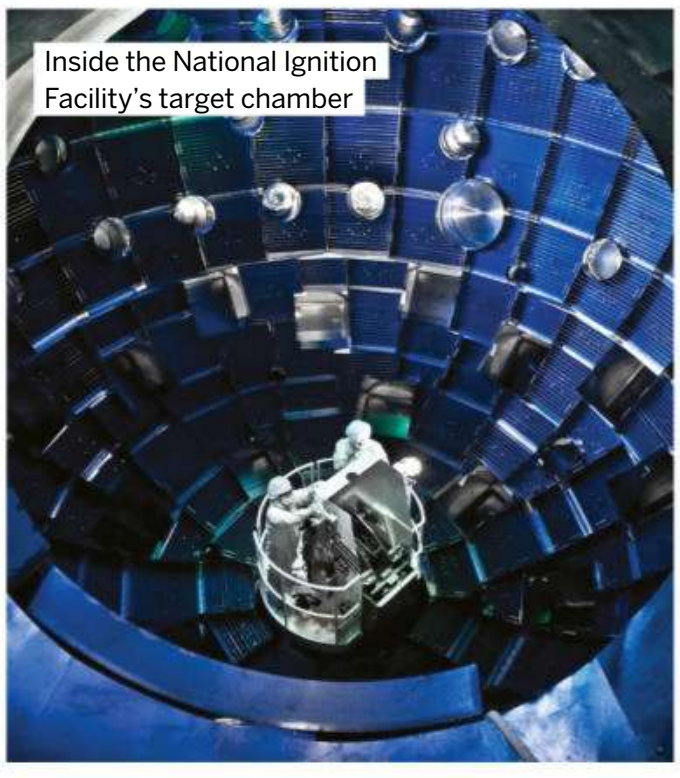
The closest black hole is only 1,560 light years from Earth

NUCLEAR FUSION LEVELS UP

One of the biggest milestones in nuclear fusion has been achieved by the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL). In December 2022, NIF scientists conducted an experiment that, for the first time, showed nuclear fusion as a viable energy source. Nuclear fusion on Earth uses the same processes that make the Sun radiate so much energy, just on a much smaller scale.

At its core, the Sun's mass is so great that gravity forces two atoms of hydrogen to fuse and become a helium atom. As a result, energy is released. The LLNL experiment replicated that process of nuclear fusion using 192 giant laser beams all pointed at a capsule of hydrogen around the size of a piece of popcorn. The lasers compressed the hydrogen to a size more than 100 billion times that of Earth's atmosphere and heated it to 100 million degrees Celsius. Under these conditions, hydrogen atoms are forced to fuse, resulting in the release of energy.

The biggest problem with nuclear fusion isn't the ability to achieve it, but to produce more energy than is required to generate fusion. Previous fusion experiments haven't yielded more energy than what is needed to power the lasers... until now. In the 2022 experiment, scientists were able to produce enough surplus energy to power a kettle. This might not sound like much, but this is the first time that a nuclear fusion experiment has produced positive net energy. Although the technology is a long way off being a green and abundant source of energy, this breakthrough is a promising step in the development of commercial nuclear power.


Inside the National Ignition Facility's target chamber

© Alamy / Getty

PRESERVED MAMMOTH FOUND

There aren't many bigger breakthroughs in the world of palaeontology than the discovery of well-preserved prehistoric animals, such as a woolly mammoth. On 21 June 2022, the mummified remains of an ice-age juvenile mammoth were found by gold miners in Yukon's Klondike region. The young specimen, named Nun Cho Ga, is thought to have been around a month old and was encased in permafrost around 30,000 years ago. The baby mammoth was likely grazing on grassland when it got stuck in the mud and quickly died. Permafrost occurs when the water molecules in soil and mud freeze and remain frozen for more than two years. This process of preservation keeps soft tissue such as muscle, skin and even DNA intact until it is unearthed. The future for Nun Cho Ga remains uncertain, but palaeontologists will be learning from the discovery for many years to come. "As an ice-age palaeontologist, it has been one of my lifelong dreams to come face to face with a real woolly mammoth," said Dr Grant Zazula, a Yukon palaeontologist "That dream came true. Nun Cho Ga is beautiful and one of the most incredible mummified ice-age animals ever discovered in the world."

Did you know?

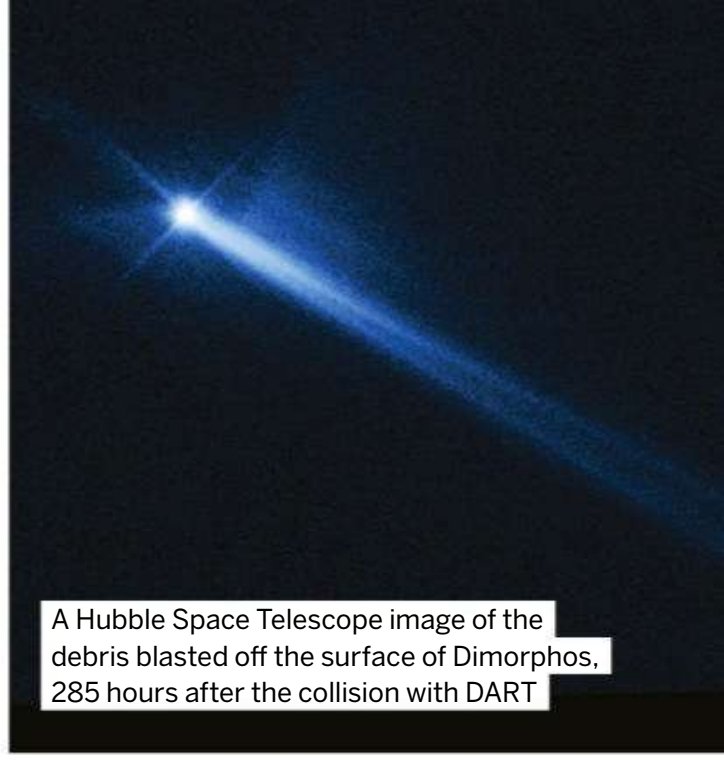
Four-metre-long turtles existed around 80 million years ago

Nun Cho Ga, the baby woolly mammoth found in Yukon, Canada

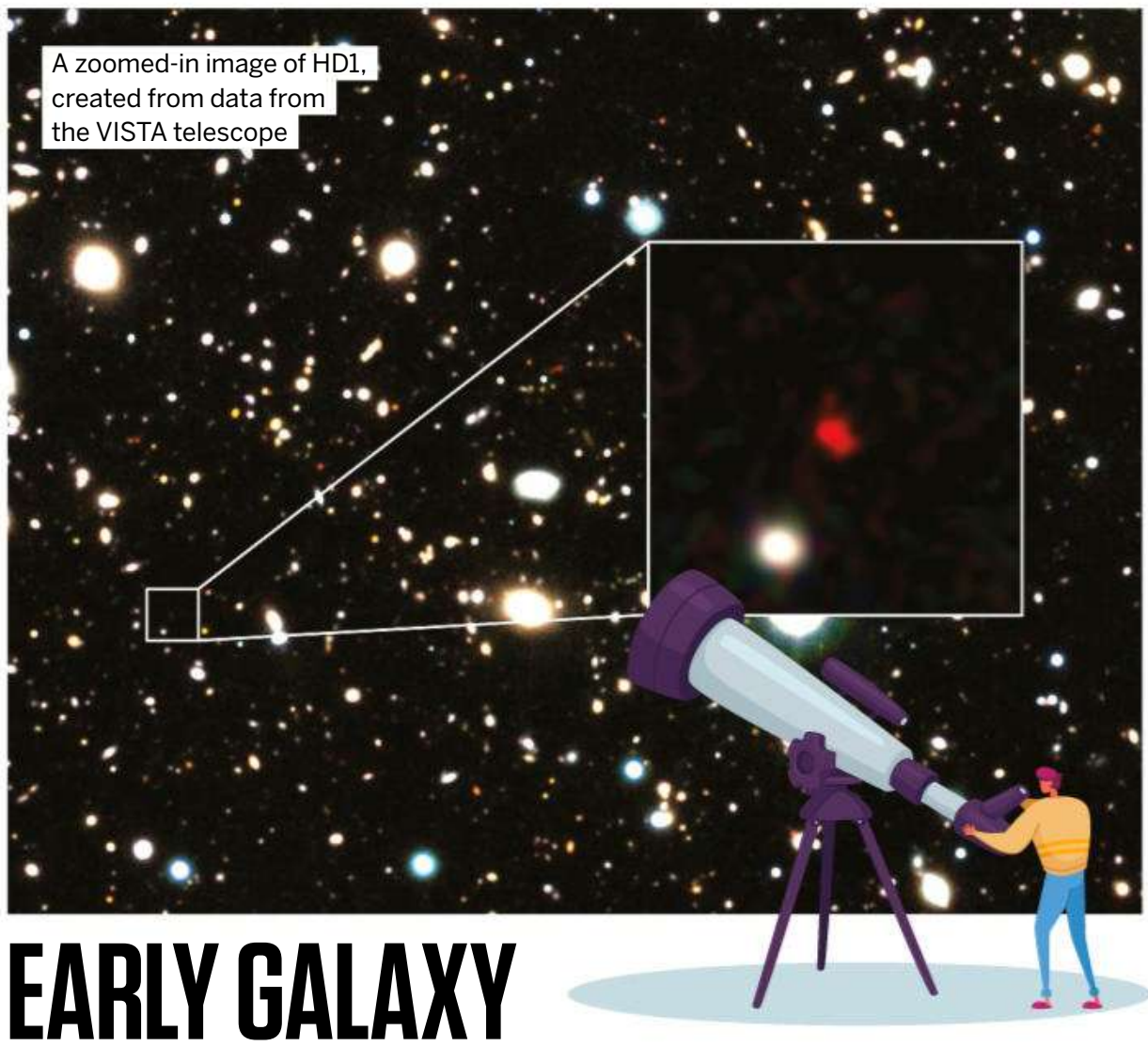
THE ASTEROID SMASHER

On 26 September 2022, NASA's Double Asteroid Redirection Test (DART) spacecraft impacted its asteroid target, Dimorphos. At launch the DART spacecraft weighed 610 kilograms, carrying roughly 40 grams of hydrogen propellant for in-space propulsion. It was powered by two very large solar panels, each extending 8.5 metres. Acting as what scientists called a kinetic impactor, DART was guided using an autonomous navigation system towards Dimorphos and collided with the asteroid at roughly 14,000 miles per hour.

DART wasn't intended to completely shatter Dimorphos, but instead displace tonnes of rock from its surface and knock it off its orbit around its parent asteroid, called Didymos. Following impact, the collision caused Dimorphos to alter and reduce its orbit of 11 hours and 55 minutes by 32 minutes. DART was launched as a proof-of-concept spacecraft to demonstrate potential for the development of an anti-asteroid defence system for Earth in the future.



A Hubble Space Telescope image of the debris blasted off the surface of Dimorphos, 285 hours after the collision with DART



A zoomed-in image of HD1, created from data from the VISTA telescope

EARLY GALAXY

Around 13.5 billion light years away is HD1, the most distant galaxy ever found. After 1,200 hours of observing the galaxy using telescopes including Spitzer, the Visible and Infrared Survey Telescope for Astronomy (VISTA) and the Subaru Telescope, in April 2022 researchers revealed that a bright ultraviolet source was in fact one of the earliest galaxies to form after the Big Bang. The galaxy might be home to the very first stars in the universe, called Population III stars, which have yet to be observed. However, there are alternative theories that there might be a supermassive black hole around 100 million times the mass of our Sun at its centre. To find out what's within the newfound galaxy, the James Webb Space Telescope will cast its eye in HD1's direction in future missions.

DID YOU KNOW? The largest single-celled bacterium, discovered in 2022, is 5,000 times bigger than typical bacteria

SWAPPING HUMAN AND PIG HEARTS

In a world-first surgical procedure, cardiac surgeon Bartley Griffith at the University of Maryland, Baltimore, transplanted a pig's heart into a human chest. The patient was a 57-year-old man named David Bennett, who had been hospitalised with terminal heart failure. Bennett was one of the thousands of people awaiting life-saving surgery. However, the world is facing a shortage of human hearts for transplant. In a last attempt to help Bennett, a surgeon carried out a xenotransplantation, which takes the heart of one species and implants it into another. For Bennett that meant receiving the heart of a genetically engineered pig.

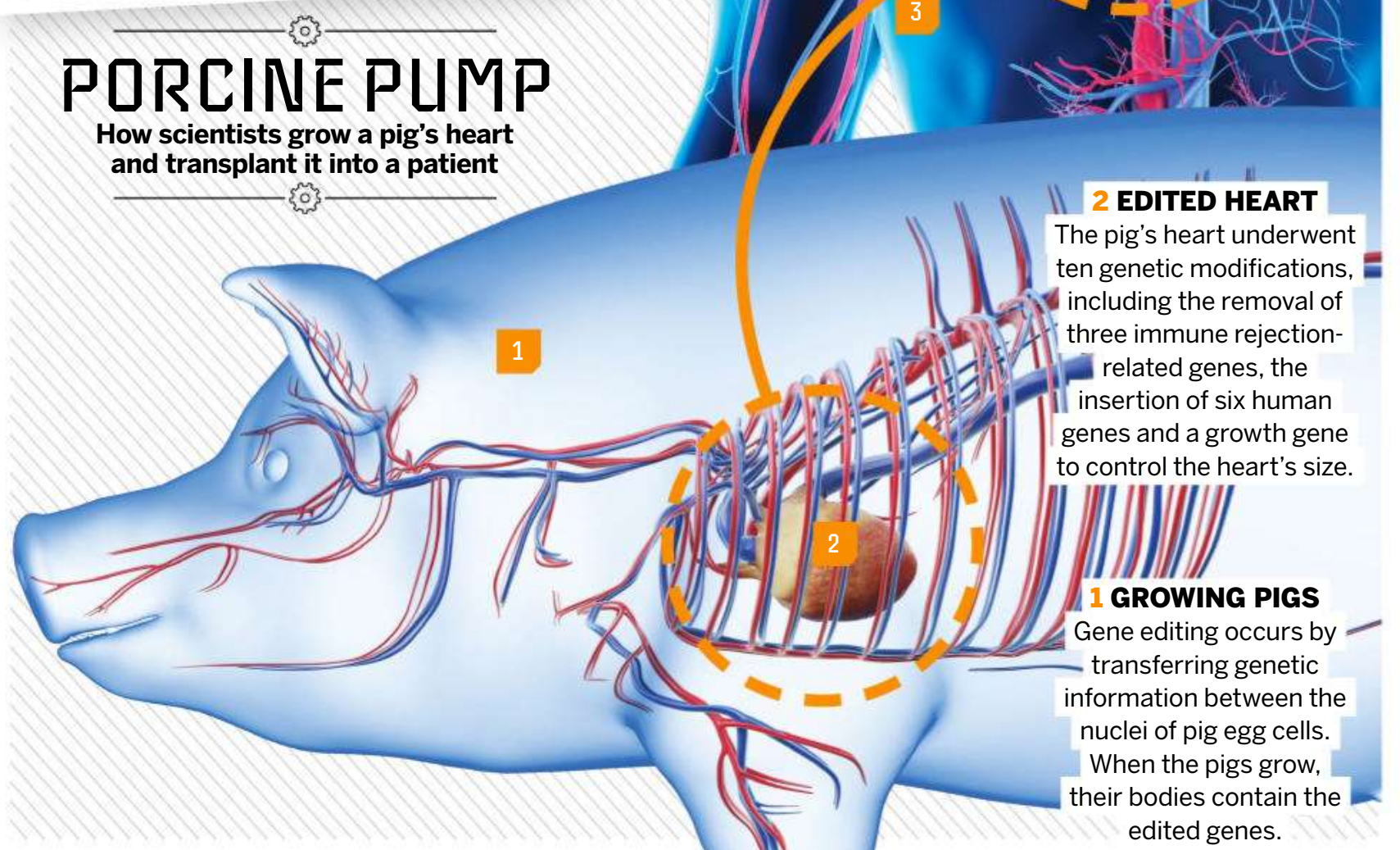
The biggest downfall of xenotransplantation is rejection from the recipient's immune system. To overcome the issue of rejection, a company called Revivicor, the successor of the company that produced the first cloned animal, Dolly the sheep, genetically engineered pigs with tissues that can reduce the risk of organ rejection. Along with the use of an experimental drug to prevent rejection, the surgery was an initial success, and the heart wasn't immediately rejected.

Unfortunately, after 60 days of living with a pig heart, Bennett passed away. Although the surgery didn't save the patient, it's still deemed a significant breakthrough for transplantations, because the heart wasn't initially rejected. Further research into xenotransplantation could offer an alternative to sourcing transplant organs.

Surgeons implanting a pig's heart into Bennett's chest

PORCINE PUMP

How scientists grow a pig's heart and transplant it into a patient



1 GROWING PIGS
Gene editing occurs by transferring genetic information between the nuclei of pig egg cells. When the pigs grow, their bodies contain the edited genes.

2 EDITED HEART
The pig's heart underwent ten genetic modifications, including the removal of three immune rejection-related genes, the insertion of six human genes and a growth gene to control the heart's size.

3 THE SWITCH
Surgeons disconnected Bennett's unhealthy heart from his circulatory system and installed the pig alternative in an eight-hour-long surgery.

4 PROMISING RESULTS
The implanted pig heart functioned well for several weeks and showed no signs of rejection.

5 CAUSE OF DEATH
Bennett's autopsy revealed no sign of organ rejection but a thickening and stiffening of heart muscle, which led to heart failure.

5 BREAKTHROUGHS IN MEDICAL TREATMENT

1 ALZHEIMER'S
A new drug called lecanemab targets a plaque that builds up in the brain of people with Alzheimer's disease, called amyloid, to slow the rate of decline.

2 AI AND SEPSIS
Using artificial intelligence (AI), researchers created an algorithm to detect several risk factors for sepsis, the leading cause of hospitalisation and death worldwide. The AI was able to detect sepsis nearly six hours earlier than traditional methods.

3 FIGHTING MALARIA
Vaccines using mRNA to tackle COVID-19 have helped research teams develop experimental vaccines which may be effective in reducing malaria infections and decreasing its transmissibility.

4 NEW ASL DRUG
The US Food and Drug Administration approved the use of a new drug called Relyvrio to treat a nervous system disease called amyotrophic lateral sclerosis (ASL). The results of a preliminary study showed that Relyvrio may slow the rate of decline for ASL sufferers.

5 BATTLING CANCER
A 13-year-old girl who relapsed with leukaemia became the first patient to receive a genetically engineered immune cells treatment, which sent her into remission.

© Getty / Government of Yukon / NASA/ESA/STScI/Hubble / University of Maryland Medical Center / Harikane et al

Did you know?

Cress seeds can grow in soil from the Moon

An image of the Chameleon I molecular cloud, 630 light years from Earth, taken by Webb's NIRCam

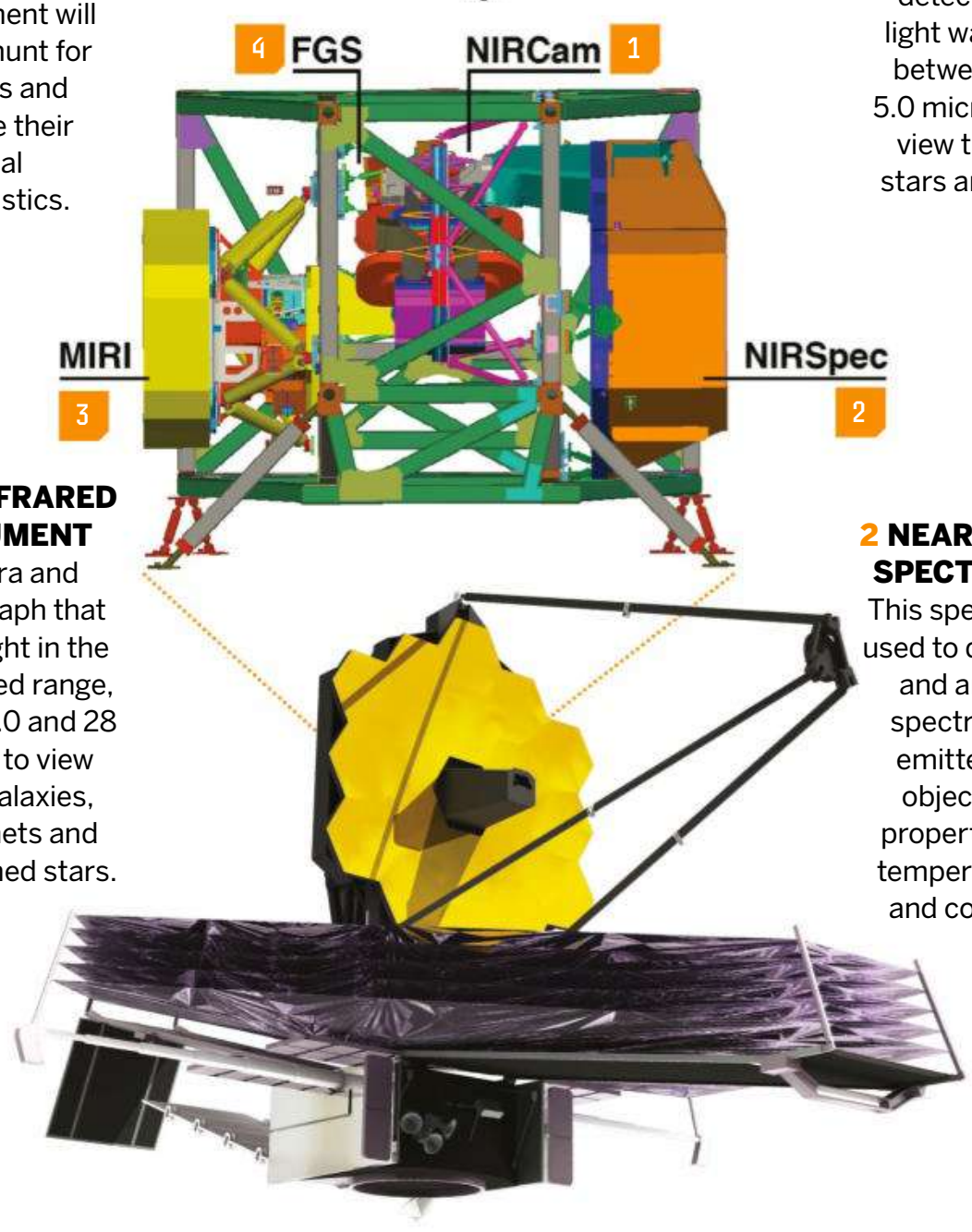
NEW VIEW OF THE UNIVERSE

The James Webb Space Telescope was conceptualised in 1989, launching over 30 years later in 2021. However, it wasn't until 2022 that Webb released the most detailed images from around the universe ever seen. As a space telescope, Webb is equipped with several instruments that allow it to record and capture different wavelengths across the electromagnetic spectrum, revealing galaxies, nebulae and stars in unprecedented detail. Webb's first deep-field images were taken in July 2022 and showed a star-forming region in the Carina Nebula that's known as NGC 3324.

Since then, Webb has taken a whole host of images from across the universe, attempting to reveal the secrets of space. One of the most ambitious projects for Webb is to look back at the first galaxies that formed following the Big Bang. So far Webb has observed galaxies that formed only a few hundred years after the creation of the universe. Along with exploring deep space, Webb has taken a closer look at celestial objects much closer to home. From snapping the clearest image of Neptune's rings and a clear view of Jupiter's Great Red Spot to detecting atmospheric compounds of exoplanets hundreds of light years away, Webb has opened astronomers' eyes to many different aspects of the universe.

WEBB'S EYES

How the next-generation space telescope explores the cosmos



4 FINE GUIDANCE SENSOR, NEAR INFRARED IMAGER AND SLITLESS SPECTROGRAPH

This instrument will be used to hunt for exoplanets and investigate their physical characteristics.

1 NEAR-INFRARED CAMERA

NIRCam is the primary imager that detects infrared light wavelengths, between 0.6 and 5.0 micrometres, to view the earliest stars and galaxies.

3 MID-INFRARED INSTRUMENT

A camera and spectrograph that can see light in the mid-infrared range, between 5.0 and 28 microns, to view distant galaxies, faint comets and newly formed stars.

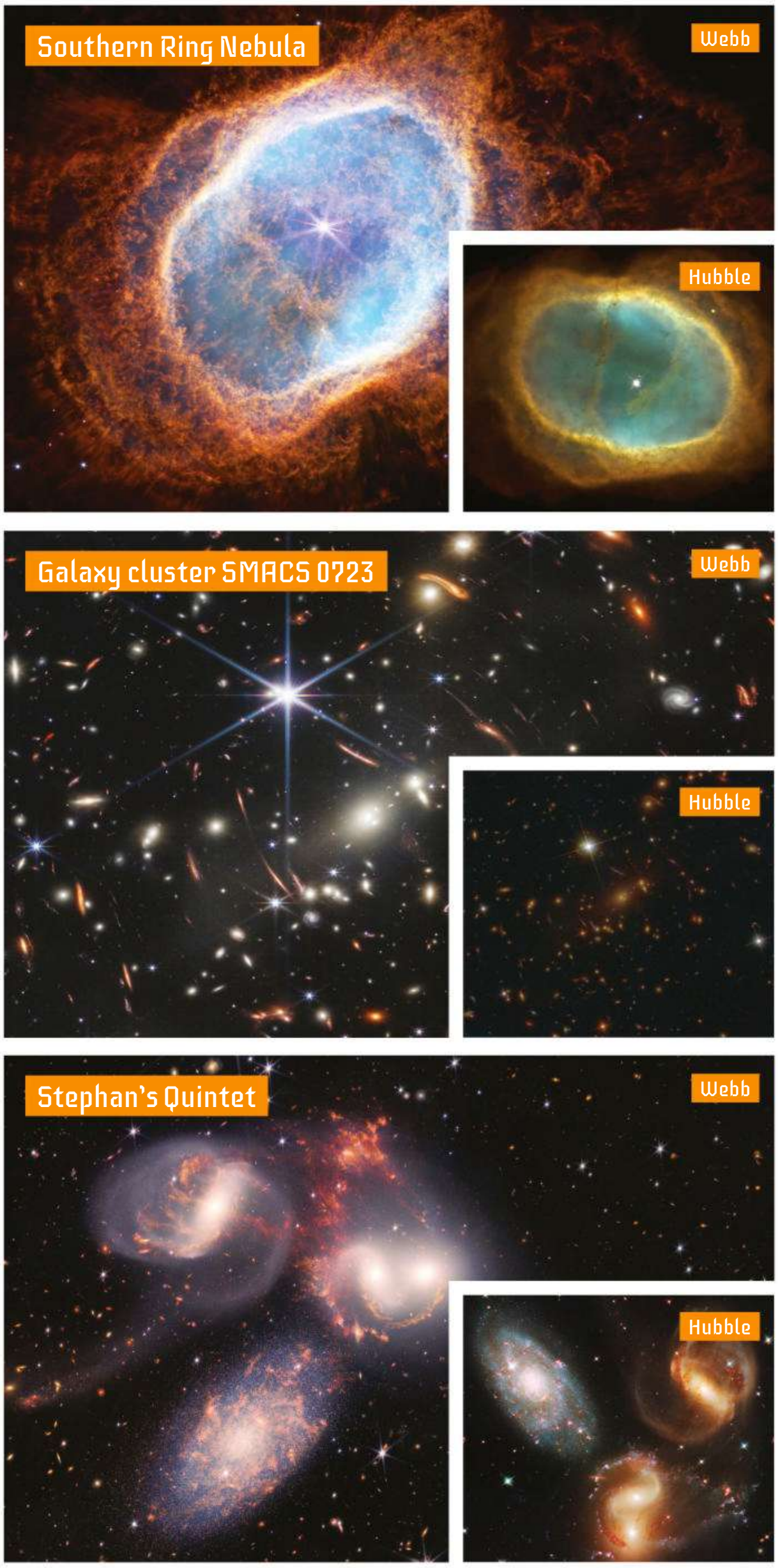
2 NEAR-INFRARED SPECTROGRAPH

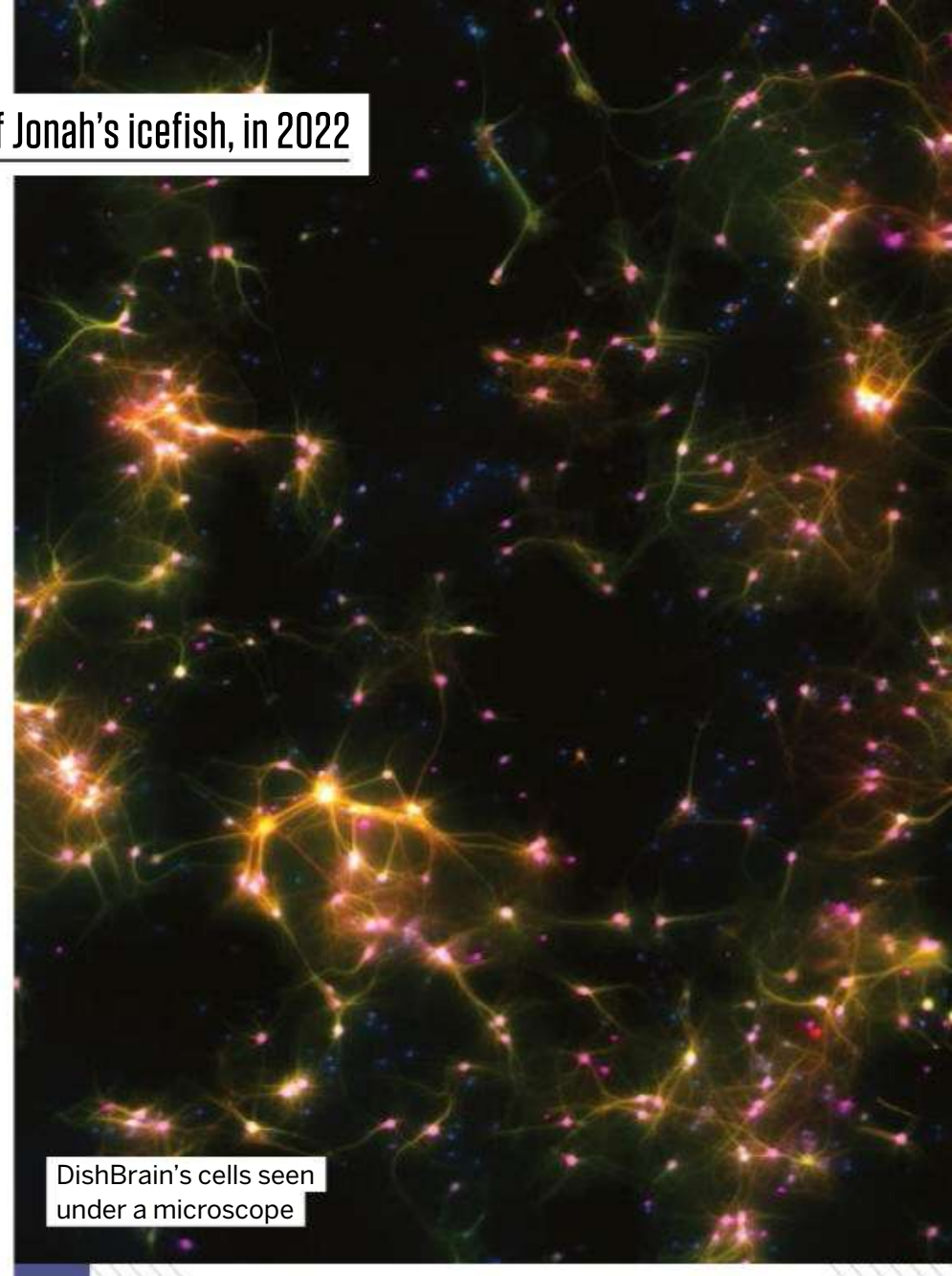
This spectrometer is used to disperse light and analyse the spectrum of light emitted from an object to reveal properties such as temperature, mass and composition.

DID YOU KNOW? Researchers discovered the largest fish colony, 60 million nests of Jonah's icefish, in 2022

HUBBLE VERSUS WEBB

Same place in space, different telescope





DishBrain's cells seen under a microscope

LAB-GROWN BRAIN CELLS PLAY PONG

Researchers have demonstrated for the first time that laboratory-grown brain cells can perform tasks. The brain cells, which the researchers named DishBrain, were grown from stem cells taken from mouse embryos and grown in a petri dish until it was populated by 800,000 cells. The mini-brain was then connected to a Pong-like computer game via electrodes. These electrodes were fired either on the right or left of the dish to indicate which side the ball was on and its distance from the paddle. DishBrain quickly learned to play the game after only five minutes, demonstrating what the researchers call synthetic biological intelligence (SBI). "This new capacity to teach cell cultures to perform a task in which they exhibit sentience – by controlling the paddle to return the ball via sensing – opens up new discovery possibilities with far-reaching consequences for technology, health and society," said Dr Adeel Razi, director of Monash University's Computational and Systems Neuroscience Laboratory.

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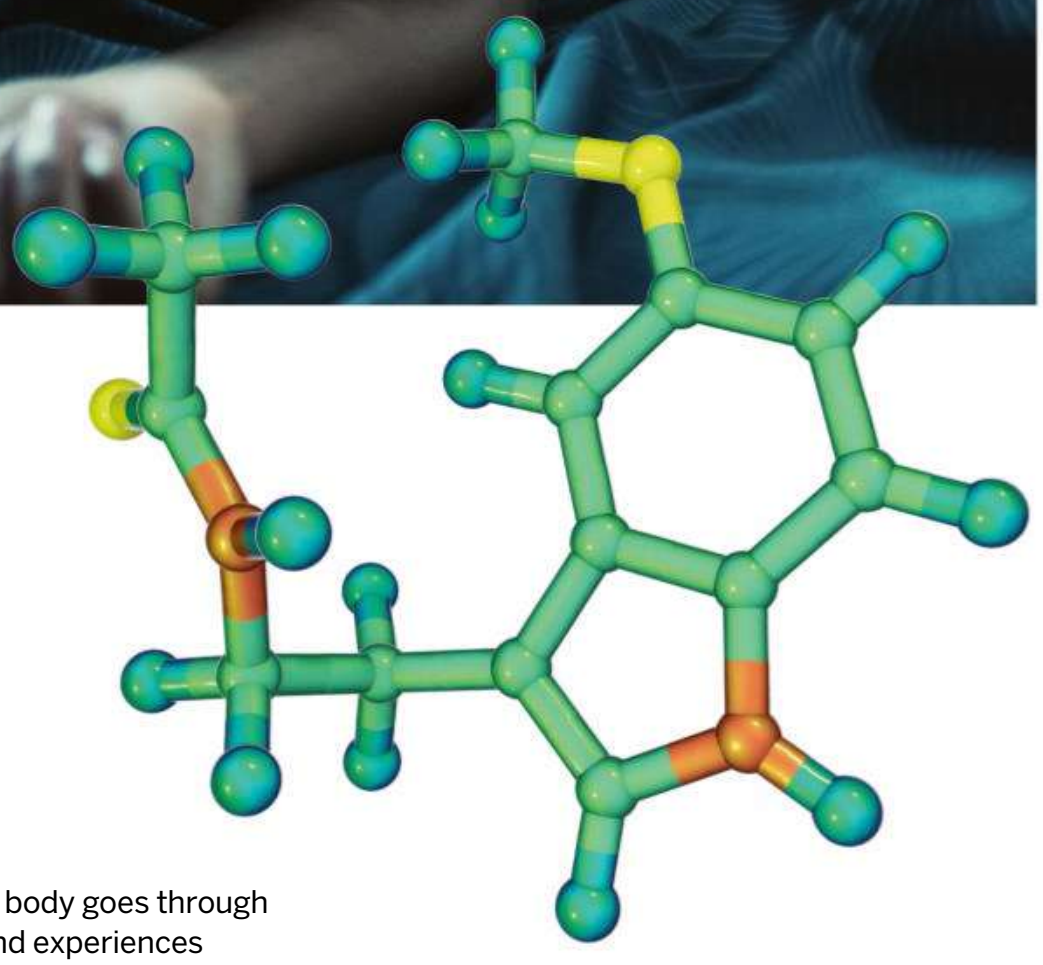
Sleeping helps regenerate damaged cells in your body

WHY DO WE SLEEP?

The science behind your body's ability to power down at night

WORDS **SCOTT DUTFIELD**



The release of a sleep hormone called melatonin helps us drift off each night

Humans spend about a third of their entire lives asleep, but scientists still aren't entirely sure why. The human body is governed by a 24-hour sleep-wake cycle known as circadian rhythm. This internal clock coordinates the body's physical and mental systems as the body transitions from alertness to sleep. It does this by responding to the changes in natural light in your environment. As natural light dims and night falls, the circadian rhythm kicks the body's melatonin production into gear. Melatonin is a hormone that helps the body enter the sleep portion of the sleep-wake cycle. And humans aren't alone in having an internal body clock – countless species, including plants, fish and insects, all experience their own circadian rhythm.

Did you know?

Most adults need seven to nine hours of sleep per night

Once we're asleep, our body goes through four to six sleep cycles and experiences physical changes in temperature, heart rate and brain activity. It's also a regenerative time for the body. During sleep, many different growth hormones are released to repair and replace any cells that have been damaged or that have died.

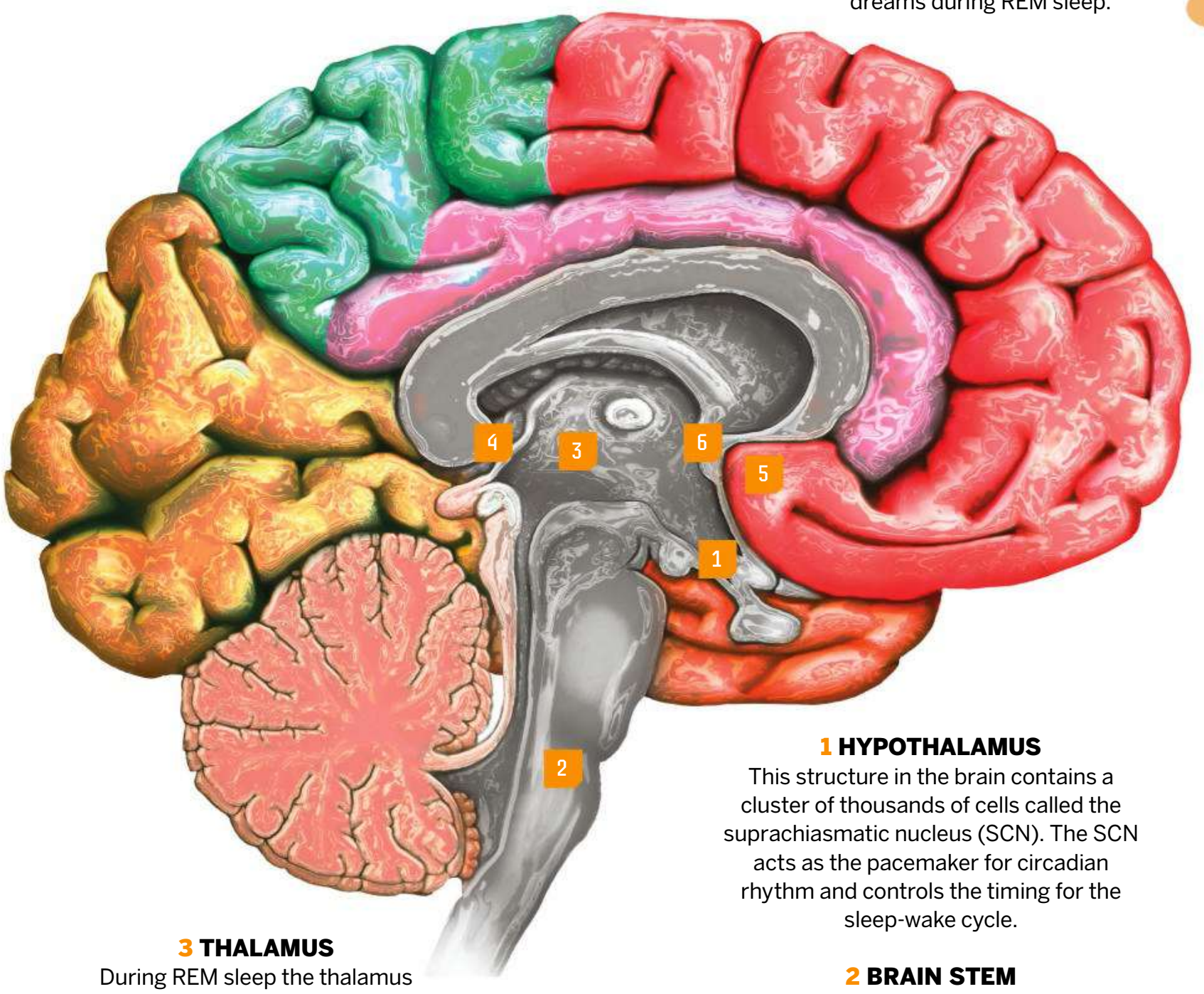
Sleep has also been linked with immune system support and the consolidation of memories. Some studies have even shown that sleep helps the brain flush out some toxins that build up inside it during the daytime.

A lack of sleep can prove fatal. A series of rodent studies conducted in the late 1980s revealed the negative impacts of sleep deprivation. Researchers discovered that all study rats that had been completely deprived of sleep died or were "sacrificed when death seemed imminent" between 11 and 32 days. All other basic needs, such as food and water, were met, and no other physical causes of death were identified. The benefits of getting a good night's sleep are abundant, but the answer to why we and the majority of other animals on Earth evolved wake-sleep cycles remains unclear. Some evolutionary theories suggest that sleep may be a survival function to keep animals out of harm's way during the night, conserve energy and reduce competition for resources.

DID YOU KNOW? The average person spends around 26 years asleep during their lifetime

INSIDE THE SLEEPING MIND

What parts of the brain are involved with sending us to sleep?



1 HYPOTHALAMUS

This structure in the brain contains a cluster of thousands of cells called the suprachiasmatic nucleus (SCN). The SCN acts as the pacemaker for circadian rhythm and controls the timing for the sleep-wake cycle.

2 BRAIN STEM

This is the communication centre between the hypothalamus and the body's muscles, sending signals for them to relax during sleep.

3 THALAMUS

During REM sleep the thalamus becomes slightly more active, sending signals to the cerebral cortex about images and sounds for dreams.

4 PINEAL GLAND

The SCN signals the pineal gland to produce melatonin to induce sleeping. This typically occurs in the absence of natural light.

5 BASAL FOREBRAIN

Cells in the basal forebrain release a chemical called adenosine that increases a person's need for sleep, known as a sleep drive.

6 AMYGDALA

An almond-shaped portion of the brain that provides the emotional content of dreams during REM sleep.

THE LONGEST SLEEPER

Snoozing more than any other animal on Earth is the koala, which clocks up to 22 hours of sleep per day and uses the remaining few hours to eat eucalyptus leaves. The reason these nocturnal feeders spend so much time asleep is because of their diet. The typically toxic leaves of the eucalyptus tree contain cyanide-like compounds that are fatal for some, but not koalas. Koalas are able to break down the toxic compounds among the 500 grams of leaves they consume per day. However, this comes at a cost. Metabolising the toxic eucalyptus leaves takes up a lot of energy, and they're also very low in nutrients. It makes you wonder why they love them so much.

Koalas snooze away the majority of their day

THE FOUR STAGES OF SLEEP

1 NON-RAPID EYE MOVEMENT (NREM)

The initial transition from consciousness to unconsciousness. During this light sleep stage, muscles relax and heart rate slows down along with breathing and brain waves. This stage can last for up to five minutes.

2 SECOND NREM

Over the next hour or so, sleepers enter a deeper stage in the sleep cycle. Heart rate and breathing patterns are reduced, along with the body's temperature. During this stage, eye movements also cease.

3 THIRD NREM

The deepest sleep stage, all vital signs reach their lowest levels and the muscles are fully relaxed. This stage typically lasts for up to 40 minutes. It's believed that this is the most restorative stage in the sleep cycle.

4 RAPID EYE MOVEMENT (REM)

Brain activity picks up during this stage, but the muscles enter atonia, or temporary paralysis. The eyes also enter a state of rapid movement beneath the eyelids. This is the stage where dreaming typically occurs.

© Getty

FIGHTING ALLERGIES

How antihistamines work to calm allergic reactions when your body's immune system overreacts

WORDS **AILSA HARVEY**

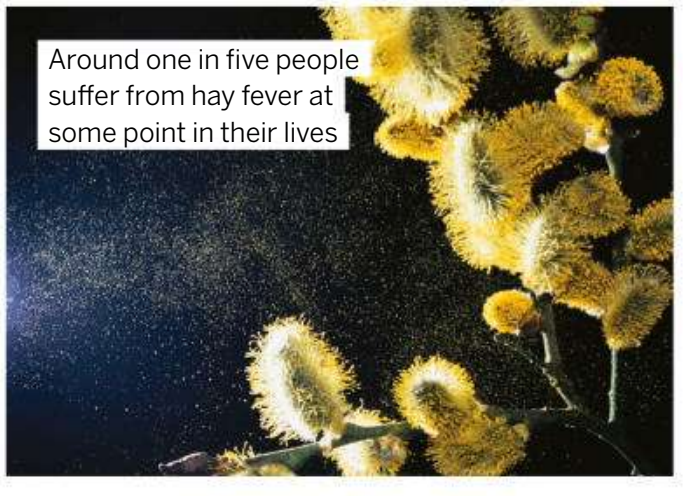
Histamine molecules are vital messengers that the body produces to keep biological systems functioning efficiently. However, in some instances levels of histamines rise too high. This is often due to allergic reactions – incidents where the immune system is overly sensitive to something that's usually harmless to others. This could be in the form of a runny nose and itchy eyes caused by high pollen levels or the swelling that can ensue after eating foods such as nuts.

Many people who suffer from allergic reactions have an antihistamine prescription from their doctor, although the use of this group of medicines isn't limited to treating allergies. As their name suggests, antihistamines block the effects caused by histamines. The drugs come in a variety of forms and can be taken as pills, chewable tablets, liquids, eye drops and nasal sprays.

There are two main types of antihistamines: sedating antihistamines and non-sedating antihistamines. Those that work against the histamines of the central nervous system can make those who take them feel drowsy. For this reason, these medications are occasionally used to treat short-term insomnia. Sedative antihistamines are a preferred option for many people whose symptoms are also impacting their sleep.

Did you know?

Most antihistamines can be used during pregnancy



Around one in five people suffer from hay fever at some point in their lives

The time at which antihistamines are taken impacts how they work. For hay fever sufferers who know that the high pollen levels will bring on an allergic response in them, antihistamines can be taken before going outside. This stops the reaction from taking place. Meanwhile, those who take them after encountering an allergen will reduce the severity of the symptoms.

hay fever or other upper respiratory allergies:
■ runny nose ■ sneezing
■ itchy, watery eyes
■ itching of the nose or throat
Warnings
Do not use if you have ever had an allergic reaction to this product or any of its ingredients or to an antihistamine containing hydroxyzine.
Ask a doctor before use if you have liver or kidney disease. Your doctor should determine if you need a different dose.
Ask a doctor or pharmacist before use if you are taking tranquilizers or sedatives.
When using this product
■ drowsiness may occur
■ avoid alcoholic drinks
■ alcohol, sedatives, and tranquilizers may increase drowsiness
■ be careful when driving a motor vehicle or operating machinery
6 years and over
Other information
■ do not use if blister unit is broken o
■ store between 20° to 25°C (68° to
Inactive ingredients
corn starch, FD&C blue #1, hyprom
lactose, magnesium stearate, polyd
polyethylene glycol, povidone, titani
dioxide, triacetin

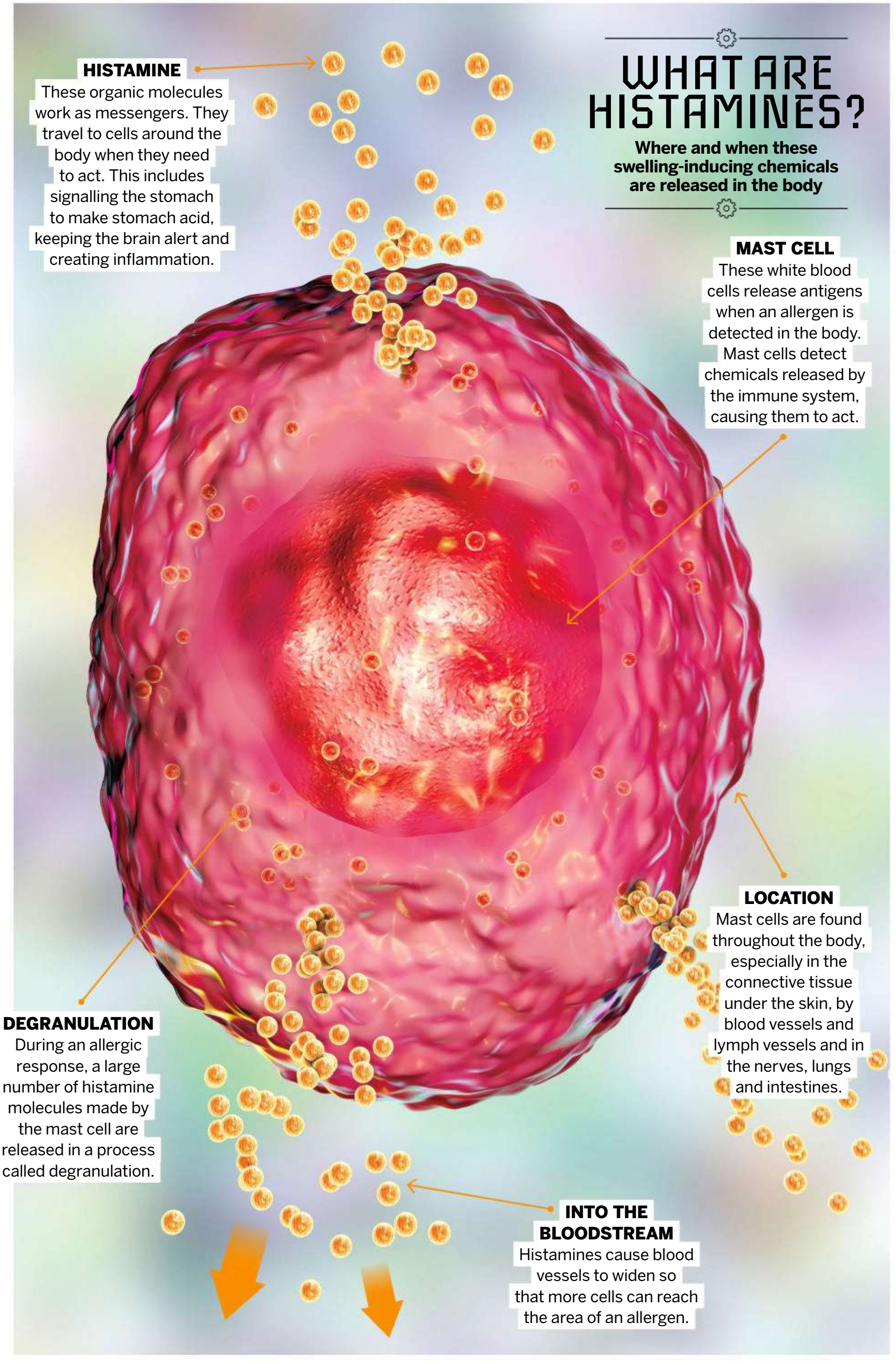
The dose of antihistamine an allergy sufferer is prescribed varies depending on age and other factors

CAN YOU HAVE TOO MUCH?

When suffering from allergies, it's important to know how much medication you should take. First you need to check the recommended dosage, which will be printed somewhere on the medication packaging or on the leaflet inside. When taking antihistamines, only take one type at a time. Taking more than the recommended dosage can result in antihistamine poisoning. The symptoms of this are very varied due to the wide variety of antihistamines. Some of the signs of antihistamine poisoning are feeling sick, blurred vision and drowsiness, an increased heart rate and headaches.

Usually, the impact of taking too much antihistamine won't materialise until around six hours later. You should consult a doctor if you experience signs of antihistamine poisoning. These symptoms might be your body adjusting to normal doses of the medication. But if it is due to high levels of antihistamine, the doctor may give you activated charcoal to absorb the toxins from the body.

DID YOU KNOW? Bees and wasps have histamine in their venom to cause swelling and irritation


HISTAMINE
These organic molecules work as messengers. They travel to cells around the body when they need to act. This includes signalling the stomach to make stomach acid, keeping the brain alert and creating inflammation.
WHAT ARE HISTAMINES?
Where and when these swelling-inducing chemicals are released in the body
MAST CELL
These white blood cells release antigens when an allergen is detected in the body. Mast cells detect chemicals released by the immune system, causing them to act.
LOCATION
Mast cells are found throughout the body, especially in the connective tissue under the skin, by blood vessels and lymph vessels and in the nerves, lungs and intestines.
DEGRANULATION
During an allergic response, a large number of histamine molecules made by the mast cell are released in a process called degranulation.
INTO THE BLOODSTREAM
Histamines cause blood vessels to widen so that more cells can reach the area of an allergen.

5 COMMON USES

1 HAY FEVER
This is an allergic reaction to allergens such as pollen, dust mites or animal fur, causing cold-like symptoms. Hay fever tablets, nasal sprays or eye drops contain antihistamines.

2 INSECT BITES
Mepyramine maleate is an antihistamine found in insect bite creams that are applied to the skin. Meanwhile, diphenhydramine is a common antihistamine used in oral tablets for itchy bites.

3 CONJUNCTIVITIS
Cetirizine, fexofenadine and loratadine are administered for conjunctivitis, an allergic reaction that affects the lining of the eye called the conjunctiva.

4 HIVES
This itchy rash can be an allergic reaction to foods, sweat, plants and even sunlight. Tablets that contain the antihistamines loratadine, cetirizine or diphenhydramine usually help relieve hive symptoms.

5 MOTION SICKNESS
When the body is moving but the eyes aren't processing the direction or speed of travel, histamines are released in the body. As these attach to receptors in the brainstem, the vomit response is triggered.

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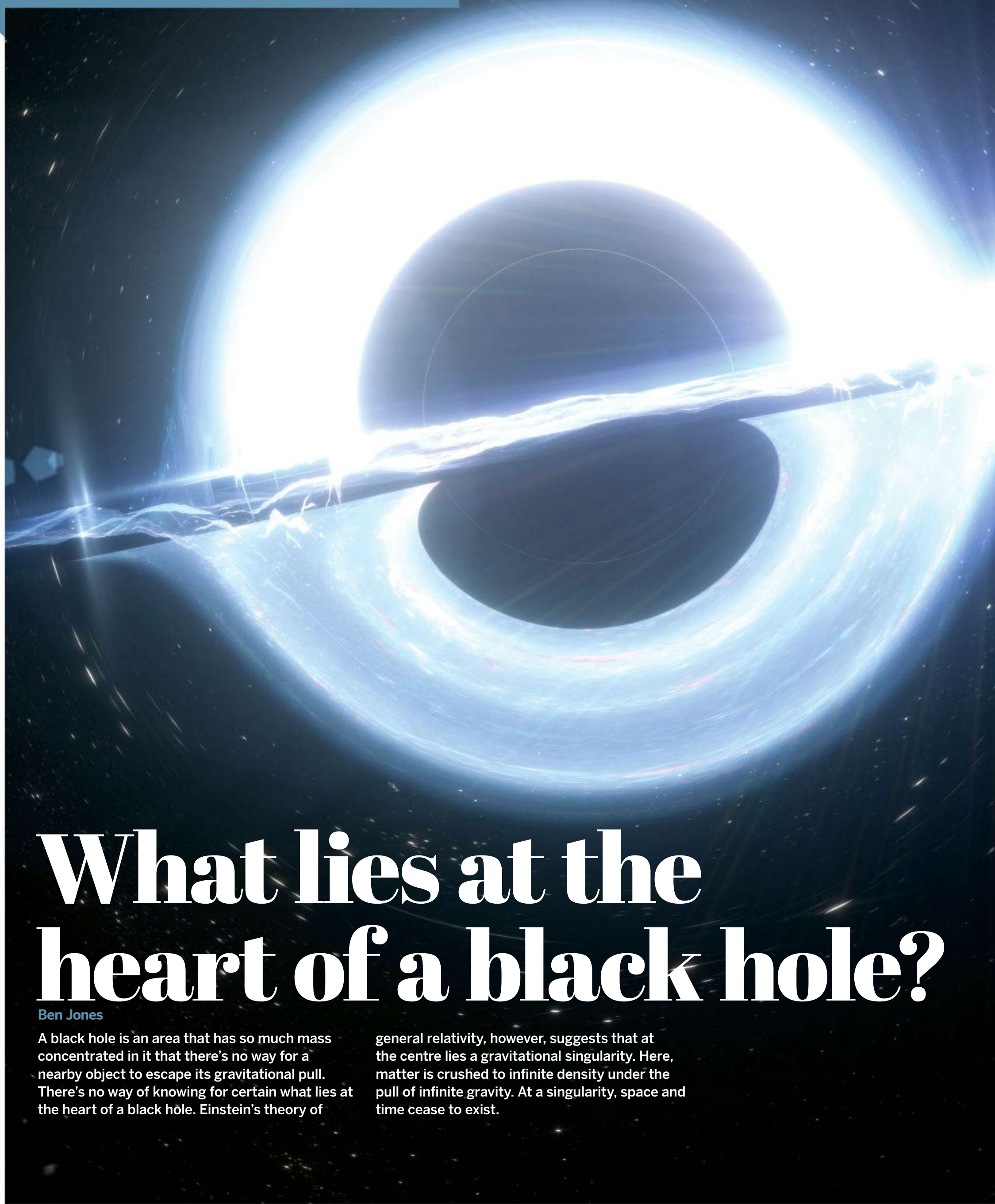


What lies at the heart of a black hole?

Ben Jones

A black hole is an area that has so much mass concentrated in it that there's no way for a nearby object to escape its gravitational pull. There's no way of knowing for certain what lies at the heart of a black hole. Einstein's theory of general relativity, however, suggests that at the centre lies a gravitational singularity. Here, matter is crushed to infinite density under the pull of infinite gravity. At a singularity, space and time cease to exist.

WHAT IS THE UK'S MOST POISONOUS WILD MUSHROOM?

Irene Sadler

Many people think brightly coloured fungi are more poisonous, but the deadliest in the UK is the death cap, *Amanita phalloides*. It grows in grassland under oak, horse chestnut and beech trees. With its pale-brown cap and white stem, it resembles a few other mushrooms that are good to eat, which is why you really need to know your fungi when foraging. Eating just half a cap could poison you enough to kill you. It would start with vomiting and diarrhoea, followed by delirium, liver failure and a coma after several days, and death a week or two later. Immediate hospital treatment usually saves lives, although it depends on the amount of mushroom eaten and the length of time between eating and receiving medical care. Most fatal mushroom poisonings worldwide are caused by eating the death cap, mistakenly thinking it's an edible species. Fly agaric, a red fungi with white spots, is from the same family and is also poisonous.

WHY DO WE SOMETIMES GET A 'LUMP' IN OUR THROATS WHEN WE'RE ABOUT TO CRY?

Lara Worthy

That 'lump' is actually not a lump at all, but a counter-reaction to the body's automatic nervous system. When humans are exposed to stressful situations – like situations that would cause them to cry or get angry – the body, due to the genetic evolutionary nature of humans to 'fight or flight', automatically increases blood flow to vital organs and muscles. Unfortunately, one of the ways the body achieves this is by opening the glottis – the vocal folds in the throat that humans use to generate vibrational noise – in order to allow your lungs to receive more inhaled oxygen than normal. While increasing available oxygen, which can be beneficial in stressful moments, it causes any human who wishes to swallow to fight against their body's automatic nervous system for control of the glottis' positioning, causing that distinctive sore pain in the throat.

Did you know?
Tears are secreted by the lacrimal gland

What is the postman butterfly?

Anton Schmetkov

The postman butterfly is a native species of northern South America. It has large, long wings with an orange-red stripe down each forewing, which warn potential predators like birds that it's poisonous. It seems to get its name from the fact it follows the same route from flower to flower each day.

WHAT'S THE DIFFERENCE BETWEEN A REGULAR AND QUANTUM COMPUTER?

Steven Baker

Normal computers use principles of quantum mechanics to represent information in strings of ones and zeros, called 'bits'. Quantum computers take these principles even further and use individual atoms, photons, ions or electrons to represent information in something called 'qubits'. Quantum mechanics shows that these particles can exist in a superposition of states, and qubits can this way represent zeros, ones and a superposition of both. As qubits can store more information than ordinary bits, these computers have the potential to be much faster than the humble laptop.

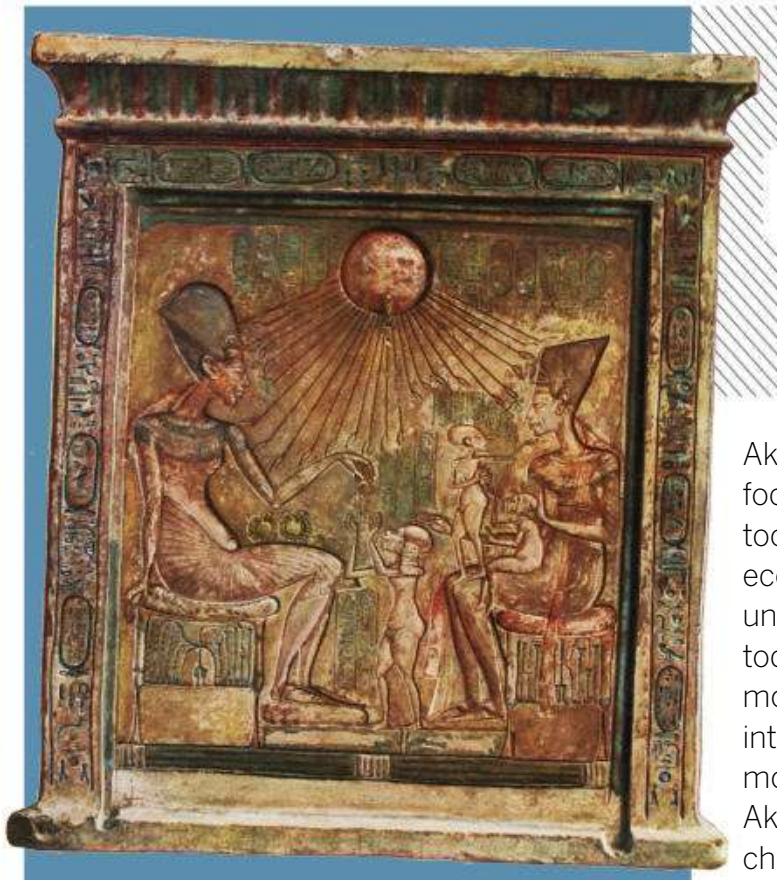
© Getty

BRAINDUMP

WHAT IS THE HARDEST NATURAL MATERIAL ON EARTH, AND WHY IS IT SO TOUGH?

Helen Sleet

Diamond is currently thought to be the hardest natural material on Earth, having a hardness of ten out of ten on the Mohs scale of mineral hardness. Diamond is made up of carbon atoms that share strong covalent bonds – where electrons are shared between atoms – and these are equally spaced in a lattice arrangement. These atoms cannot move, which is what makes diamonds so hard. However, computer simulations have shown that recently discovered rare natural materials wurtzite boron nitride and lonsdaleite are respectively 18 and 58 per cent harder than diamond. However, they have yet to be tested in laboratory settings due to their rarity, and so have yet to claim the title of the Earth's hardest material.



Why was Egyptian pharaoh Akhenaten so controversial?

Emmy Smith

Akhenaten closed the most important temples in Egypt to focus all religious activity on his favourite god, the Aten, which took the form of the Sun disc. This had a huge ideological and economic impact on the country, and made him very unpopular. Because of the focus on one god, some people today regard Akhenaten as the person who introduced monotheism, but many people disagree with this interpretation. Many religions, including Christianity, are monotheistic – meaning belief in one god. In addition, Akhenaten had himself depicted with both male and female characteristics. There's a lot of disagreement about why he did this – did he actually look this way?

WHY DOES YOUR VOICE SOUND DIFFERENT TO YOURSELF?

@ajka

When we listen to someone else speaking, it's the change of pressure in the air that our ear picks up via the eardrum, which in turn vibrates the bones in the middle ear. This causes fluid in the cochlea (inner ear) to move hair cells deep in our ears and send an electrical signal to our brain.
Our own vocal cords vibrate our skull, and caverns such as our sinuses can amplify this by passing the middle ear and going straight to the cochlea. Low frequencies like bass sounds prefer this method of direct contact, which can make us think our voice is deeper than it really is.

WHY DO GIANT PANDAS ONLY EAT BAMBOO?

Jason Stewart

Although bamboo makes up the majority of giant pandas' diets, this includes up to 60 different species of bamboo. They also eat other plant material, and occasionally meat.
Although bamboo is difficult to digest, giant pandas have evolved various adaptations, allowing them to live on it. Bamboo grows very fast and is usually plentiful, and giant pandas do not face much competition for food from other species. If it weren't for human activity, this would be a neat evolutionary niche to occupy. Unfortunately, climate change, along with habitat destruction and fragmentation, are all threatening giant pandas.

Did you know?
There are over 9,000 craters on the Moon

Is there an official name for the Moon?

Jon Winstone

The Moon is simply called ‘the Moon’. It wasn’t until as late as the 16th century that astronomer, physicist, mathematician and philosopher Galileo Galilei used a telescope to make drawings of the Moon's surface. A year later, he discovered four of Jupiter’s moons. They had similar properties to our own Moon, such as orbiting around a planet rather than the Sun, so it makes sense to call them moons. Individual names such as Io, Europa and Callisto distinguish them from our own natural satellite.

IS IT POSSIBLE TO BUILD A TELEPORTATION MACHINE?

Troy Takashi

A teleportation machine would have to accurately map every one of over a trillion atoms in the human body. If even a single particle were a fraction of a millimetre out of place, then it could have fatal consequences. The machine would have to make a copy of the atoms at the destination, which would mean that it would be less of a transporter and more of a high-tech photocopier that creates a perfect copy in a new location. This would be more like cloning than travel, and then what happens to the original?

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What is sheet lightning?

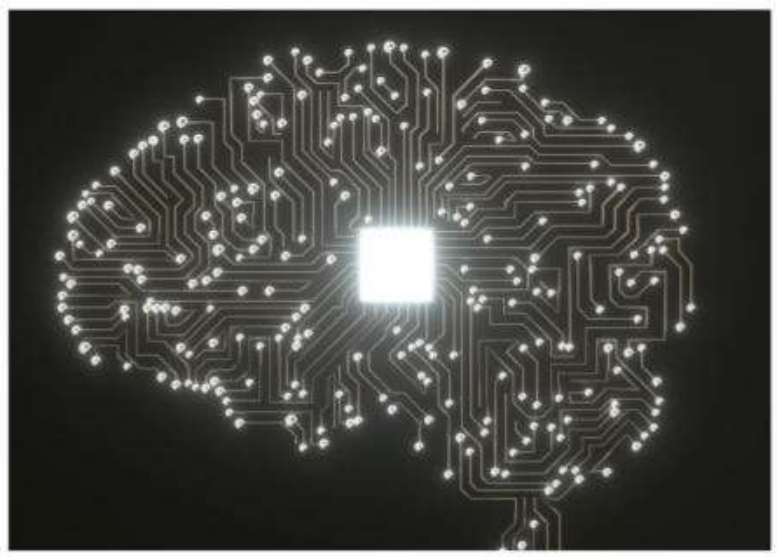
Alan Stark

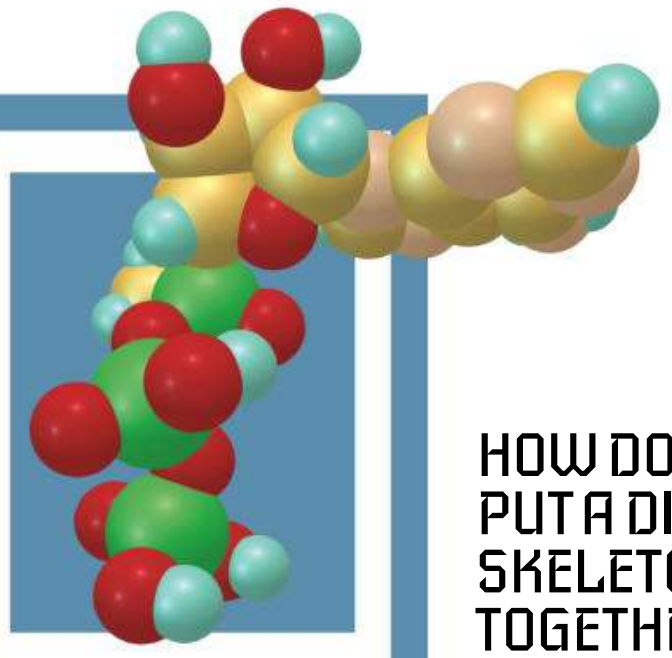
Lightning is a beautiful yet dangerous natural phenomenon that's formed in electrically charged storm systems. These enormous electrical discharges are caused by an imbalance between positive and negative charges. Exactly how lightning is formed continues to remain a mystery, and a number of different hypotheses exist. Sheet lighting is when we see a luminous white sheet during a thunderstorm. This, however, isn't a distinct form of lightning. The flash is just hidden by the clouds, making them glow either because it's really far off or it's going between the clouds.

WHAT WOULD THE AVERAGE HUMAN BRAIN'S CAPACITY BE IF MEASURED IN GIGABYTES?

Manjusha Ratti

This may take many years to be answered, if it's ever done. Our brain processes information in a way that's very different from regular computers. We're only just starting to understand how it stores memories and how these memories are linked together. Many people tried to make estimates about how it would compare to a computer, and common estimates range between one and ten terabytes (1,000 gigabytes). Others believe it's far greater at about two petabytes (a million gigabytes). Some think it's actually much smaller and our brain is just much more efficient than computers at storing information.





HOW MANY ATP MOLECULES HAVE TO BE BROKEN DOWN INTO ADP TO PROVIDE US WITH A JOULE OF ENERGY?

Anja Singh

ATP (adenosine triphosphate) is used to transfer energy to cells for biochemical processes such as muscle contraction. When the outermost bond of ATP is broken to form ADP (adenosine diphosphate), the reaction releases around 30^{500} joules per mole ($6.02214179 \times 10^{23}$ molecules) of ATP. This means we need 1.981587×10^{19} molecules of ATP to break down to ADP in order to provide a single joule of energy. If you're struggling to imagine that number, it's 1.9 followed by 19 zeros! But many of these ADP molecules are then recycled to form ATP, ready to be reused. In fact, each ADP molecule can be recycled as many as 1,000 or 1,500 times a day. It's a good job, too, as a typical human will use up their own body weight of ATP in a day!

HOW DO YOU PUT A DINOSAUR SKELETON TOGETHER?

Tracy Beale

It can be difficult to work out which bone goes where because we have no modern dinosaurs to compare the skeletons to. Birds and reptiles are similar to dinosaurs, so by carefully looking at their bones, we can be confident we can tell how dinosaur skeletons were put together.

Did you know?
The first complete dinosaur skeleton was found in 1858

WHAT IS TINNITUS AND HOW IS IT CAUSED?

Joel MacDonald

Tinnitus is a physiological disorder where an individual experiences a ringing or buzzing in their ears. There are two different types of tinnitus: subjective – the most common form of the disorder – and objective, which is considerably rarer. The difference between the two forms is whether the buzzing noise can be heard by anyone else but the sufferer, with subjective tinnitus heard only by the person in question and objective tinnitus heard by others.

Current medical opinion states that the cause of both forms of tinnitus can be traced to a number of ear conditions, including external auditory canal obstructions (earwax, for example), engorgement of the eardrum's membrane, subjection to certain

drugs like chloroquine and exposure to loud noises of high frequency. In addition, tinnitus has been linked to high blood pressure, or hypertension. Treatment usually involves the simple removal of any ear canal obstructions that may be present in the sufferer. However, in severe cases, surgery and meditative drugs like amitriptyline are also used. For persistent sufferers, hearing aids and high-frequency noise blocking devices are utilised.

Why can owls see so well at night?

Miranda Peck

Most owl species are nocturnal and have become well adapted to night vision through their evolution, enabling them to hunt and catch their prey in the dark. Many prey species are nocturnal, thus avoiding diurnal predators during the day, so being nocturnal hunters can be a good strategy. Nocturnal owls' eyes have a number of adaptations for good night vision, including their large size, the shape of their lenses, the large proportion of light-sensitive rods to colour-sensitive cones in their retinae, and relatively large corneas. However, some diurnal owls do not have particularly good vision in dark conditions, and instead are better adapted for hunting during the day.

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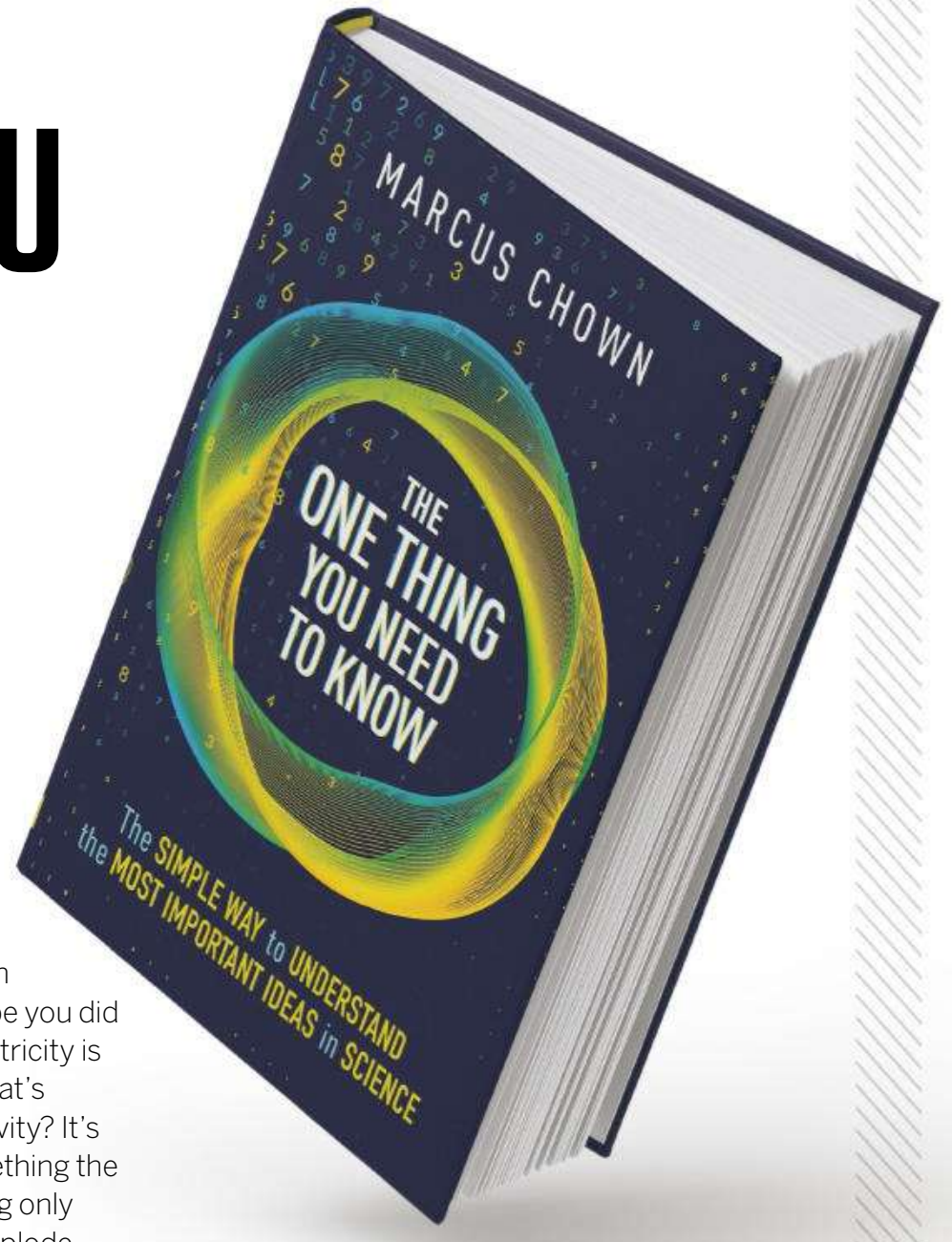


Did you know that gravity is an incredibly weak force? Maybe you did – but did you know that electricity is an incredibly strong force that's many billions of times stronger than gravity? It's so strong that if all the electrons in something the size of a mosquito were removed, leaving only the positively charged nuclei, it would explode with the same force of the meteorite impact that wiped the dinosaurs out. It's this kind of mind-blowing knowledge that author Marcus Chown has made a glittering writing career out of over the last 25 years or so. He's had around two dozen books published, mostly science, and most of those space-based. He's won the 2017 *Sunday Times* Science Book of the Year prize and the Bookseller's Digital Innovation of the Year, and has twice been a runner-up in the Royal Society Books Prize. This former radio astronomer also studied under one of the modern era's most famous physicists, Richard Feynman, before he changed track to become a writer and broadcaster.

That's what you need to know about the author, in case you were inclined to question his expertise, because in *The One Thing You Need to Know*, Chown talks in depth on a number of different topics from a range of scientific disciplines. This includes quantum physics, solar dynamics, evolutionary biology, climatology, geology and more. And he distils each chapter down to a single thing – the one thing that everyone needs to know about and that anyone can understand. The chapter on the brain, for example, opens with a subheading that reads: "The principal activities of brains are making changes in themselves." It's an intriguing idea, the promise of which is entirely fulfilled by the ten pages or so of the chapter. Chown has set himself quite a challenge with the concept for this book, but makes light work of explaining really tough, esoteric topics to the layman in a way that is both digestible and completely fascinating. He gets a little help along the way in the form of some basic annotated diagrams, but it's his writing and expertise that will really pull you along, page after page. *The One Thing You Need to Know* isn't suitable for the younger end of **How It Works**' readership, but almost anyone else will find it hard to put down.

"Chown talks in depth on a number of different topics from a range of scientific disciplines"

POLAR

WILDLIFE AT THE ENDS OF THE EARTH

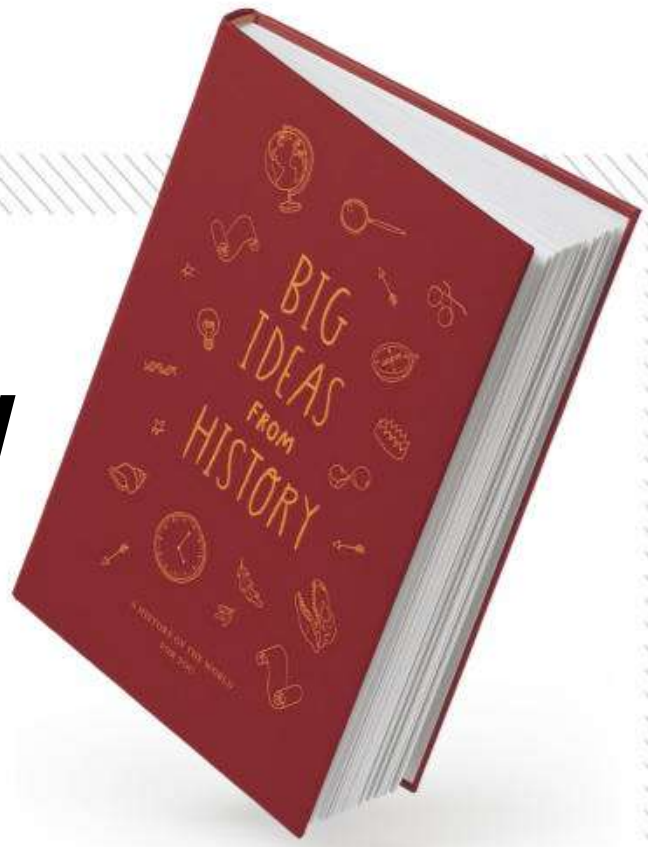
AUTHOR **L. E. CARMICHAEL**
ILLUSTRATOR **BYRON EGGENSCHWILER**
PUBLISHER **KIDS CAN PRESS**
PRICE **£17.99 / $18.99**
RELEASE **4 MAY**

Readers will be transported to the Arctic Circle and the Antarctic through the eyes of their animal inhabitants to discover what life gets up to at Earth's polar extremes. Every page counts down the year and reveals how animals at the poles not only survive but thrive in extreme conditions. Each month highlights the life of a different animal at each of the poles. For example, while the blizzard-enduring Eurasian lynx is hunting through Arctic snow in January, chinstrap penguins are diving into krill-filled Antarctic waters. There are also fun snippets of information about the poles that periodically break up the calendar style of the book, like understanding permafrost and the effects of climate change. Alongside wonderful stories about wildlife are equally stunning illustrations that bring each animal to life.

BIG IDEAS FROM HISTORY

A HISTORY OF THE WORLD FOR YOU

AUTHOR **THE SCHOOL OF LIFE**
PUBLISHER **THE SCHOOL OF LIFE PRESS**
PRICE **£22 / $32.99**
RELEASE **OUT NOW**



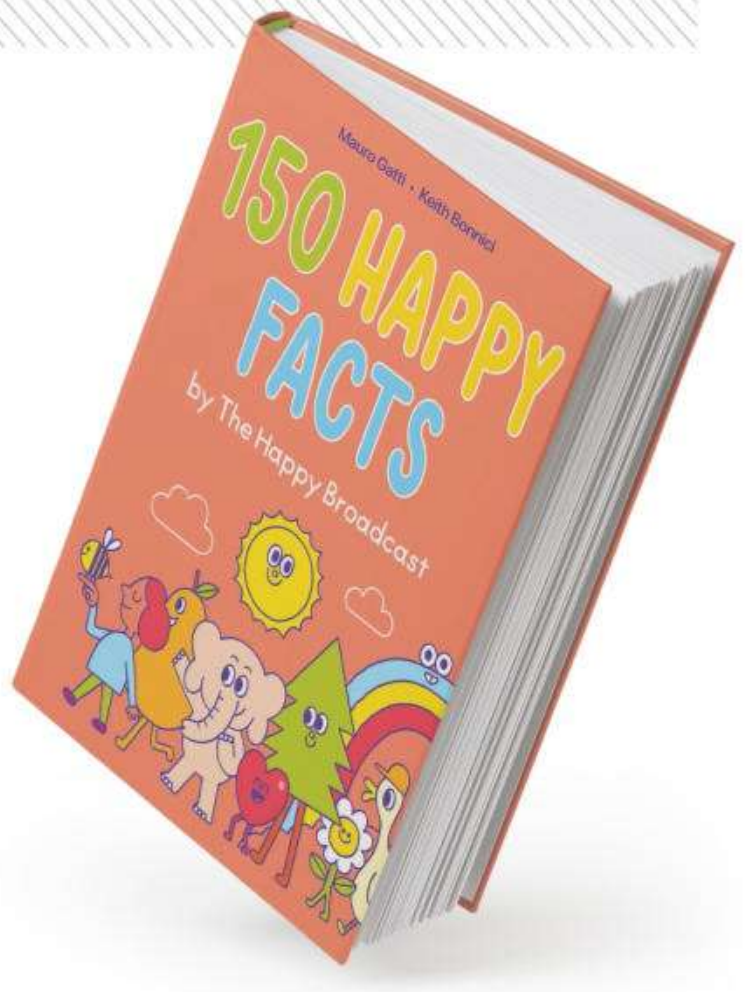
If you're often on the receiving end of questions about the history of the world from young, curious minds, then this book might be your answer. Covering a wide range of topics throughout history, such as the origins of life and the Big Bang, ancient Greek gods, the evolution of science and different concepts within society, this book is packed with information.

Although *Big Ideas from History* is clearly targeted at a young audience with an interest in history, it's not like other non-fiction children's books. It's a hefty volume with 320 text-heavy pages filled with interesting facts and stories. Breaking up the text are fun illustrations of two characters that take the journey through history with you. This book is written in a way that not only seeks to inform its readers, but also encourages them to learn from history and even prompts them to write down their big ideas for the future at the end.

150 HAPPY FACTS

POSITIVE FACTS ABOUT ANIMALS, HEALTH, SPORT AND MORE

AUTHOR **KEITH BONNICI**
ILLUSTRATOR **MAURO GATTI**
PUBLISHER **ANDREWS MCMEEL**
PRICE **£7.99 / $11.99**
RELEASE **7 MARCH**



An amazing fact can fill your mind with awe, but not all of them make you feel good. With so much negativity often circulating at the moment, this book is a welcome breath of positivity. The kinds of facts you will discover about our planet in *150 Happy Facts* are largely focused on those working to make the world a better place. For example, did you know that over 100 countries have committed to stop and reverse deforestation by the end of the 2020s? That giraffe populations have rebounded by 20 per cent since 2015? Or that sea otters hold hands with their loved ones when they nap so that they don't drift apart?

Composed by the creators of *The Happy Broadcast* – a podcast that focuses on positive outlooks and improving mental health – *150 Happy Facts* will give you something to smile about every day. The facts are categorised in sections such as the environment, technology, animals and people, with each given one page. Each one is initially summarised in a snappy sentence at the top of the page, making it perfect for a quick read, with more in-depth details available underneath. Alongside each fact is a quirky illustration, each matching the book's bright and joyful theme.

CHAMPION CHOMPERS, SUPER STINKERS

MEET THE BIGGEST, FASTEST, STRONGEST AND STINKIEST IN THE ANIMAL WORLD

AUTHOR **LINDA ASHMAN**
ILLUSTRATOR **APARNA VARMA**
PUBLISHER **KIDS CAN PRESS**
PRICE **£16.14 / $19.99**
RELEASE **8 JUNE**

Whether you've seen these animals before or they live in an environment you can only imagine, this book should teach you something new about each of its animals. From the deepest depths of the ocean to the highest trees and skies, these animals are ready to introduce themselves and show off their most impressive traits. Written from the animals' perspectives, each entry presents an engaging, humorous and sometimes dramatic poem, including sounds and actions perfectly suited to be read out loud to young children. These are combined with small paragraphs of information to explain the statistics, fun facts and justification for each animal's place in the book of extremes.

The new characters are introduced alongside vibrant yet true-to-life illustrations that will help children understand the behaviours and habitats of each animal. As you turn the page to greet the longest living, largest, tallest, strongest or stinkiest, you will learn about how these titles aid their survival in daily life. Some animals even have unique jobs, such as the ocean's artist, the river engineer and the treetop architect, making the collection a diverse and captivating read.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

2	5		8	1	9		6	3
1		3			4			9
				3		5	4	
	4		3	2	6	1		
9	3		5			6		4
7			4					
			9	4	7			6
6	2	9			3			
	1	7			5	9	3	8

MEDIUM

2					7	6		
5	9					3	7	1
				6	5			9
6	2	4	9				3	
9		5	7	3			2	
1					2	8		6
	7			1				
				7				2
			8		4	7		5

HARD

	6	7	5		2			
1						6		
					4	2		
2		8		6				
			1				4	
							3	6
	9			2				
		6	4	5	7			9
		3		9			5	1

Word search

Find the following words

EARTH
VOLCANO
NETTLE
SCIENCE
ASTEROID
SLEEP
HERO
VEHICLE
RIP
WAR
UNIVERSE
FACIAL

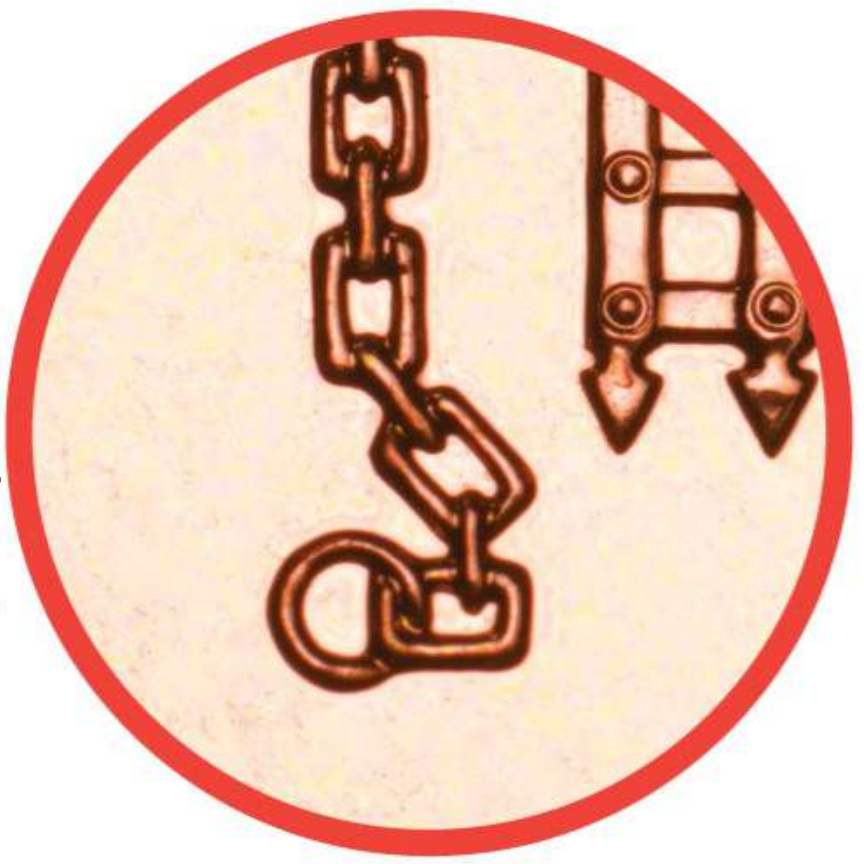
F	A	C	I	L	E	C	N	E	I	C	S	E	N	P
L	Y	H	G	A	N	S	T	Q	A	Z	A	O	W	P
B	E	A	R	T	H	F	M	T	O	D	L	H	F	J
K	O	R	M	G	I	G	E	C	H	O	E	M	L	S
U	H	E	O	L	C	A	N	U	P	L	R	H	E	O
V	I	S	U	H	E	C	L	E	C	O	X	D	R	L
O	Y	R	C	O	E	N	A	I	L	V	O	L	I	N
L	O	E	D	R	T	T	H	F	S	L	E	E	P	J
C	T	V	A	E	S	E	T	R	O	L	D	E	M	W
A	Y	I	M	H	V	O	L	C	T	A	C	I	A	L
N	E	N	Y	O	B	A	N	T	N	I	K	E	L	O
O	L	U	J	H	E	R	E	B	O	P	F	A	C	I
S	C	I	A	N	G	N	T	I	C	M	Y	U	C	A
P	W	A	R	I	K	A	F	A	C	I	A	L	H	U
R	B	E	N	A	S	T	E	R	O	I	D	U	X	B

What is it?

Hint:

Penny for your thoughts?

A



Spot the difference

See if you can find all six changes between the images below

QUICKFIRE QUESTIONS

Q1 How long does light from Earth take to reach the Moon?

- 1.255 seconds
- 12.55 seconds
- Two minutes, one second
- Two hours, one minute

Q2 How fast does a rocket need to travel to orbit Earth?

- 16,700 miles per hour
- 71,600 miles per hour
- 67,100 miles per hour
- 17,600 miles per hour

Q3 Who won the 1921 Nobel Prize in Physics

- Stephen Hawking
- Brian Cox
- Carl Sagan
- Albert Einstein

Q4 How many taste buds can be found on your tongue?

- 1,000
- 2,000
- 4,000
- 8,000

Q5 What colour is a sunset on Mars?

- Green
- Red
- Yellow
- Blue

Q6 What percentage of the world's money is stored on computers rather than cash?

- 10 per cent
- 30 per cent
- 70 per cent
- 90 per cent

Answers

Find the solutions to last issue's puzzle pages

Q1 1886
Q2 40,000
Q3 BURNS ON RE-ENTRY
Q4 AU
Q5 YELLOW AND BLUE
Q6 1957

What is it?

CAT'S EYE

Spot the difference

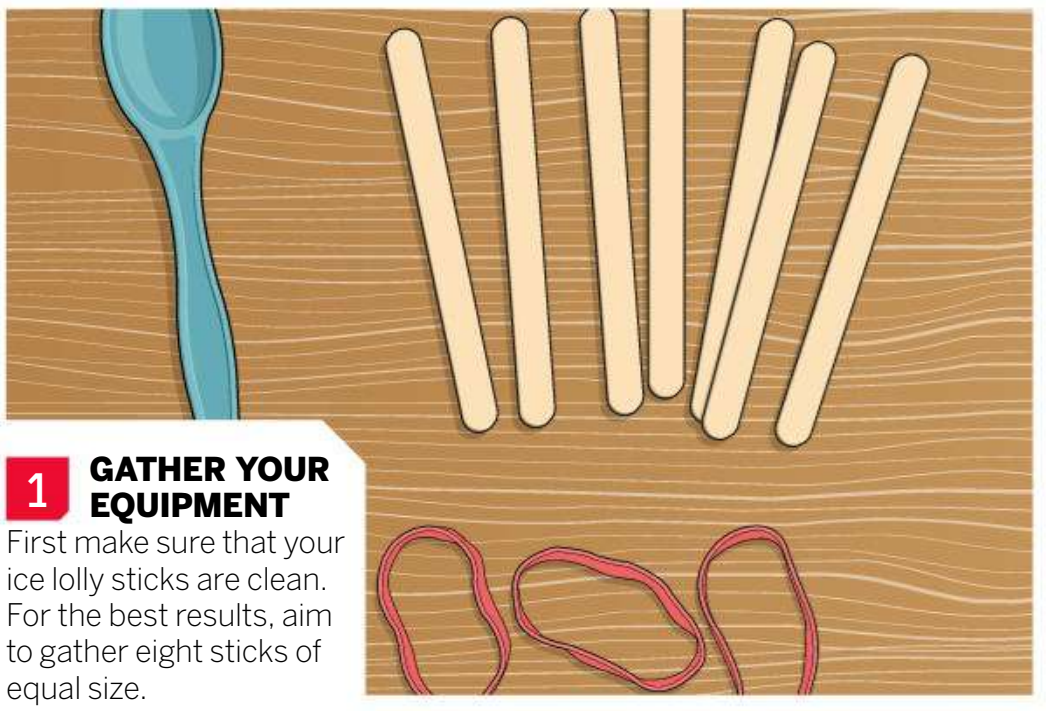
© Getty

HOW TO...

Practical projects to try at home

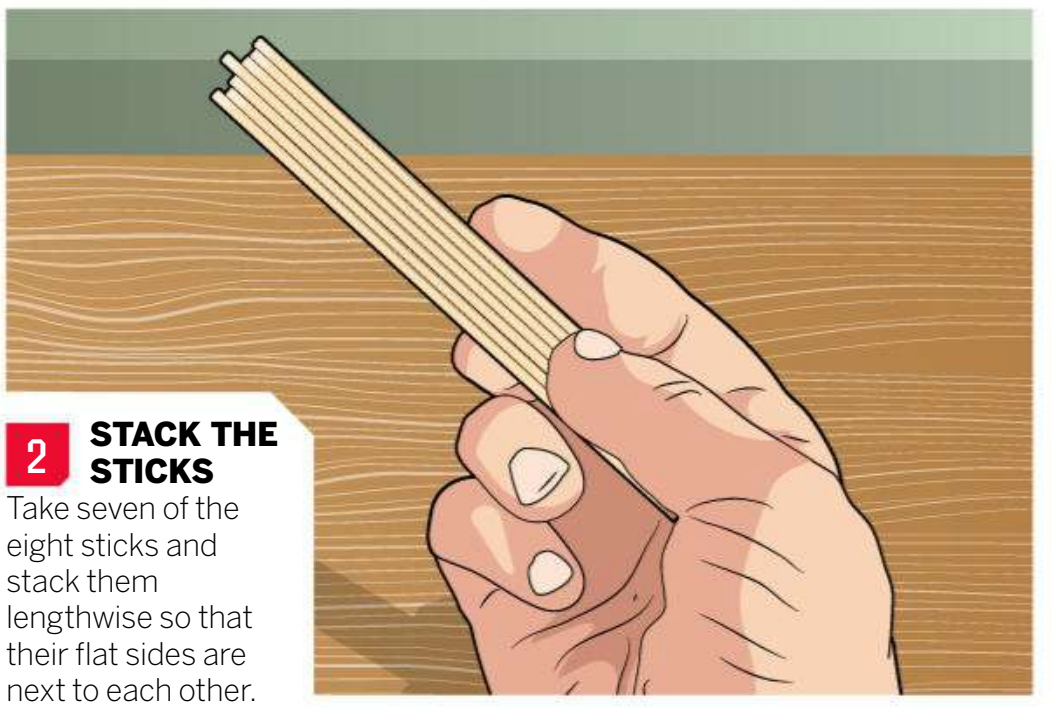
MAKE A LOLLY-STICK CATAPULT

Turn your rubbish into an awesome launching device with this simple guide



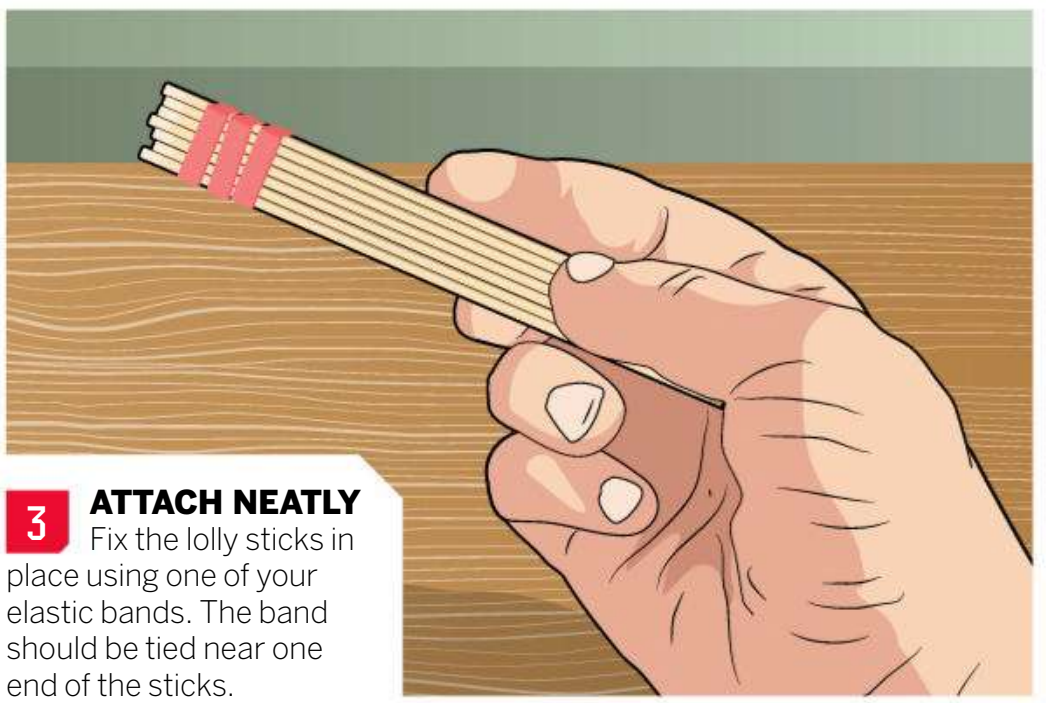
1 GATHER YOUR EQUIPMENT

First make sure that your ice lolly sticks are clean. For the best results, aim to gather eight sticks of equal size.



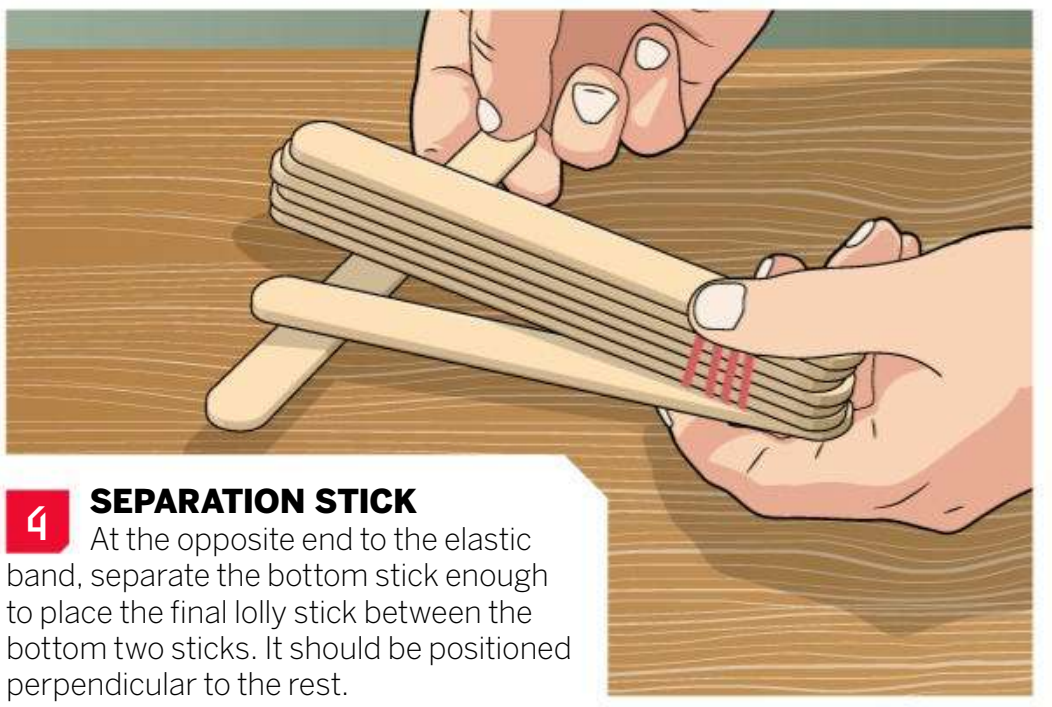
2 STACK THE STICKS

Take seven of the eight sticks and stack them lengthwise so that their flat sides are next to each other.



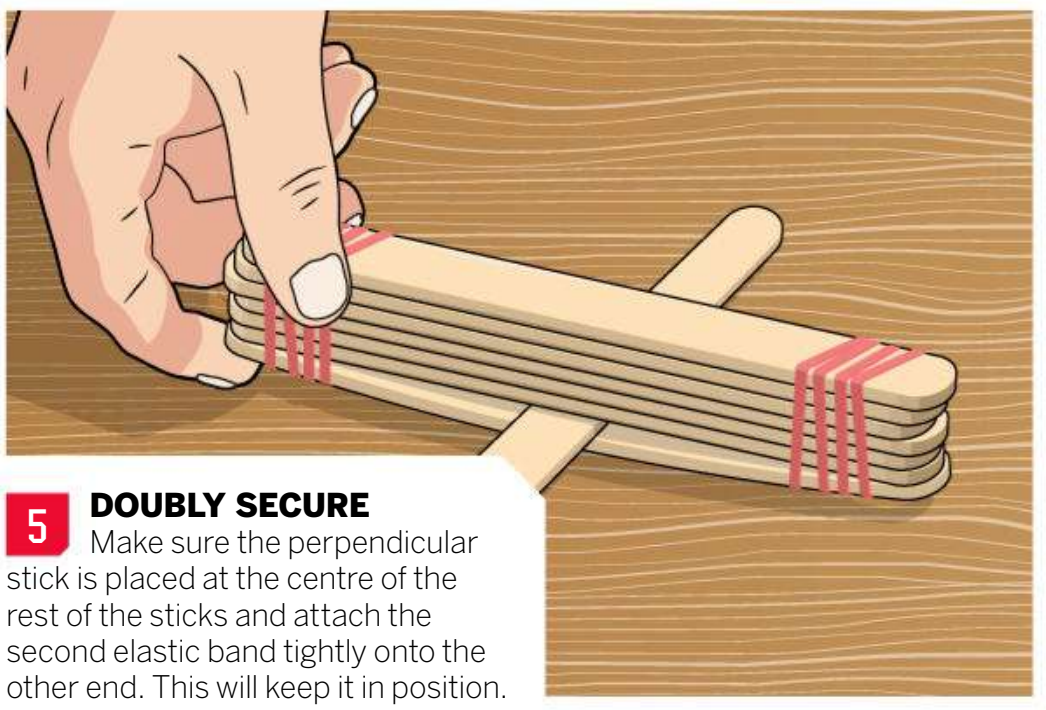
3 ATTACH NEATLY

Fix the lolly sticks in place using one of your elastic bands. The band should be tied near one end of the sticks.



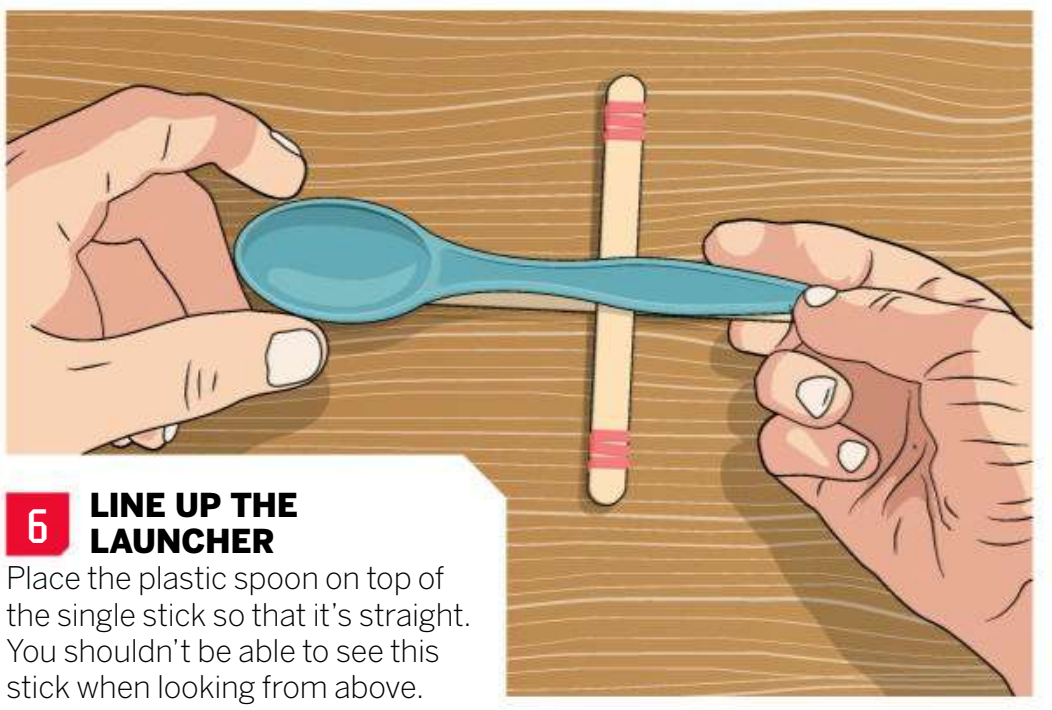
4 SEPARATION STICK

At the opposite end to the elastic band, separate the bottom stick enough to place the final lolly stick between the bottom two sticks. It should be positioned perpendicular to the rest.



5 DOUBLY SECURE

Make sure the perpendicular stick is placed at the centre of the rest of the sticks and attach the second elastic band tightly onto the other end. This will keep it in position.



6 LINE UP THE LAUNCHER

Place the plastic spoon on top of the single stick so that it's straight. You shouldn't be able to see this stick when looking from above.

KIT LIST

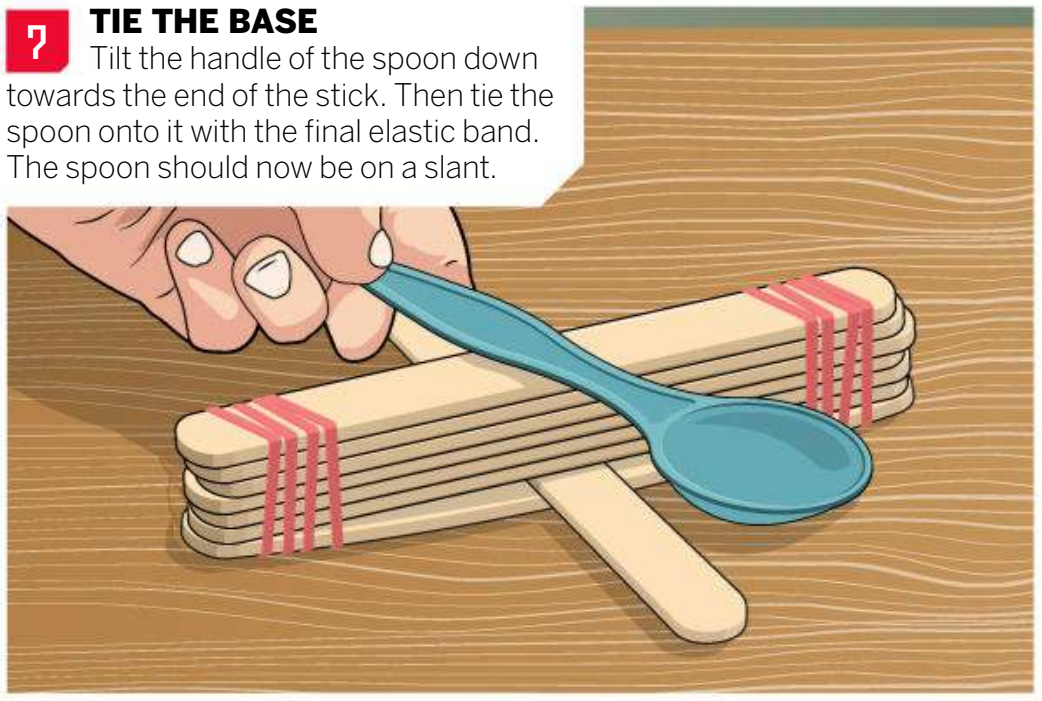
- Eight ice lolly sticks
- Three elastic bands
- A plastic spoon
- Paper, foil or small plastic balls

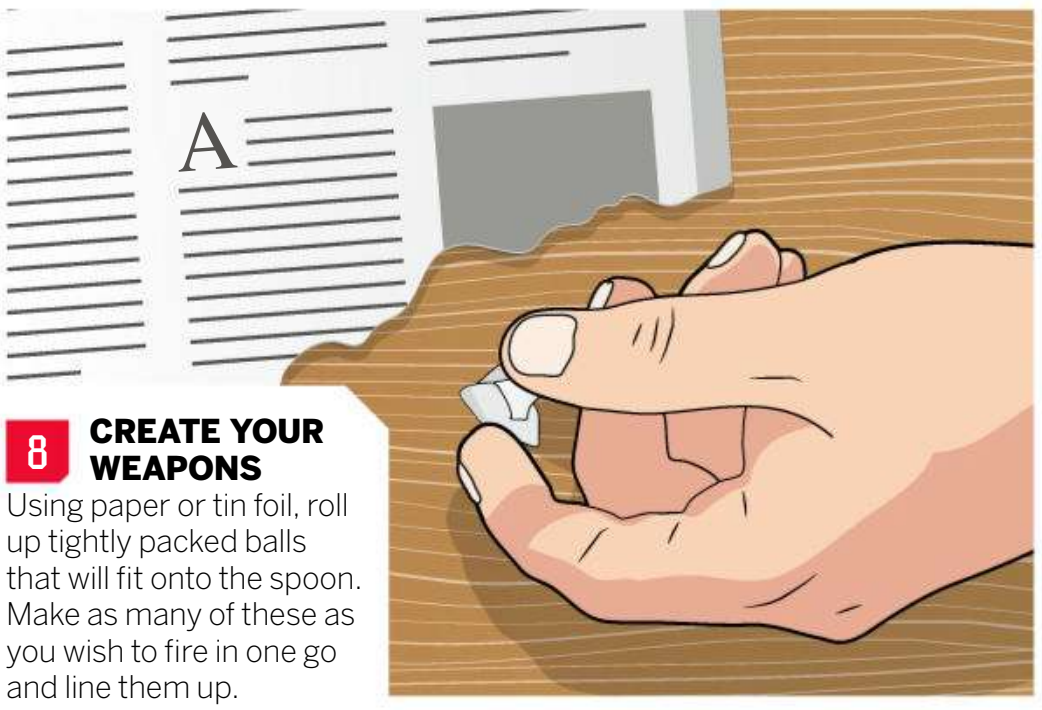
DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you

7 TIE THE BASE

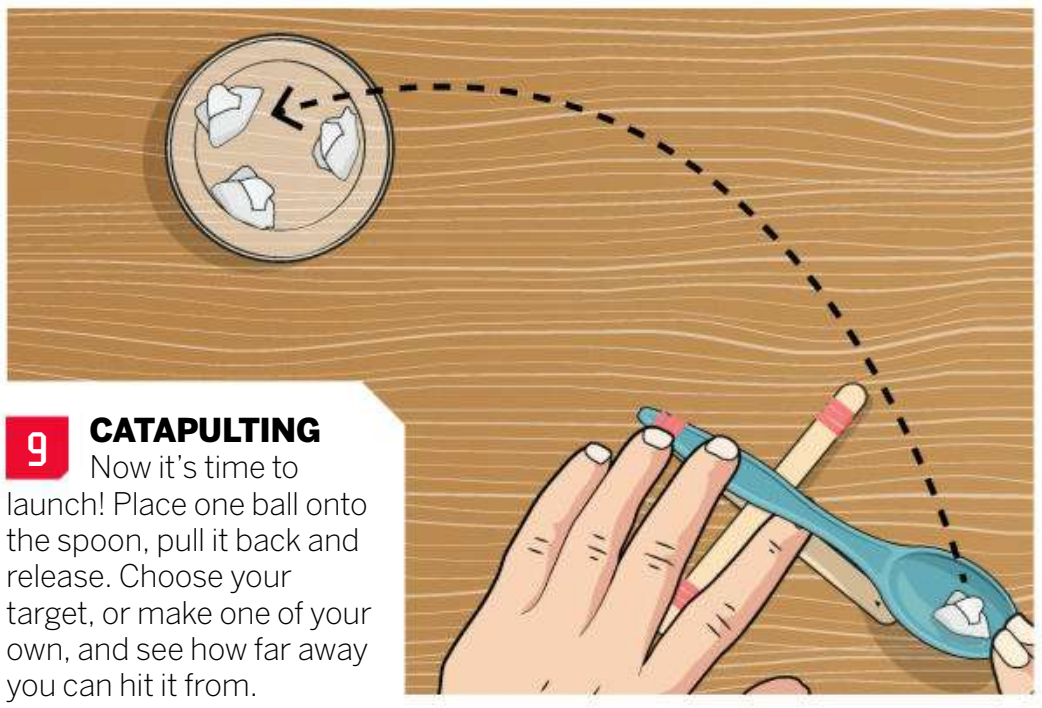
Tilt the handle of the spoon down towards the end of the stick. Then tie the spoon onto it with the final elastic band. The spoon should now be on a slant.





8 CREATE YOUR WEAPONS

Using paper or tin foil, roll up tightly packed balls that will fit onto the spoon. Make as many of these as you wish to fire in one go and line them up.



9 CATAPULTING

Now it's time to launch! Place one ball onto the spoon, pull it back and release. Choose your target, or make one of your own, and see how far away you can hit it from.

SUMMARY

Catapults work using a lever mechanism. The force that results when the spoon springs forward can be explained by Newton's laws of motion. His first law states that an object will remain at rest until there's an external force acting on it. When you're holding the spoon down, it has potential energy, which is converted into kinetic energy when you release it. You can fire the catapult load using different levels of force by choosing how far down to pull the spoon.

Another factor that changes how your catapult works is the angle of the spoon. If you slide the stack of sticks closer to the end of the spoon that's tied down, then the spoon will be more upright when at rest. This means that when firing the catapult, the balls will travel more parallel to the ground, but won't reach as high. Alternatively, sliding the sticks in the opposite direction will cause the load to be launched high into the air. Make sure to adjust your catapult based on whether you want height or distance when launching your weapons.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX
Speak your mind

The majority of curved swords came from the East

OBSERVING CURVES

Dear **HIW**,
Thank you for your magazine, which I read with great enjoyment every month. I do think you missed something within your pages in issue 172 when you answered the question: Why were some swords constructed with a curved blade? Most handheld blades are curved. Surgeons' scalpels, kitchen knives, garden secateurs and even my log-splitting maul have a curved leading edge. Curved blades cut better than straight ones. The force behind the blade is applied to a smaller target area, where the leading curve of the blade meets the object to be cut rather than being spread out along the whole length of the edge at once.

What makes katanas and sabres appear more obviously curved than most other blades is the fact that the back is curved too. They don't have a straight, thicker spine to strengthen them. A sword like that would have been used on the move – rapid hand-to-hand fighting whether from horseback or on foot. The person wielding it would want something as light as possible with the maximum reach so as to be able to hit opponents from as far away as possible while not getting tired. Almost equally important, a sword should be easy to remove from a hacked opponent before some other enemy has at you. Asking the next person attacking you to hold on a minute while trying to wrench out the big fat sword you just wedged between his pal's ribs wasn't really a good battlefield tactic.
Liam Baldwin

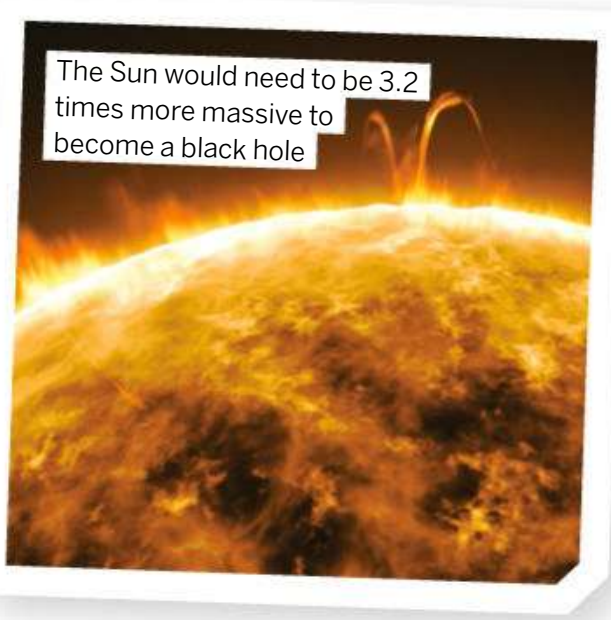
LETTER of the MONTH

In issue 172 we explained how curved swords enabled more efficient attacks from horseback. Attackers used these shaped swords to slash opponents rather than stab them. However, your letter offers another interesting element of curved blades. The smaller surface area of a curved blade in contact with an object, compared with a straight one, means that more pressure is applied from the curved blade when the same force is used.

WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH
THE ONE THING YOU NEED TO KNOW
Wouldn't it be easier to understand science with just one central notion from which everything else flows?

SUN FORMATION

Dear **HIW**,
Is the Sun made by a black hole? What would this be the exit of?
Alfred Booth


The Sun would need to be 3.2 times more massive to become a black hole

The Sun formed 4.6 billion years ago out of a collapsing cloud of gas and dust. It's a star that emits huge amounts of light, among other forms of radiation, while black holes are what's left behind after massive stars collapse under their own gravity and explode in a supernova. Light can't escape these objects because the gravity of black holes is so strong. In 2022 the Hubble Space Telescope discovered that black holes can create new stars not dissimilar to our Sun. To do this, gas that escapes a black hole can interact with areas of dense gas within a galaxy.

DESIGNING SUDOKU

Dear **HIW**,
I always enjoy the sudoku section of your puzzles page because I like most challenges with numbers. How long have people been doing them?
Hugo Miller

Sudoku is a fun number puzzle which challenges deductive reasoning. The first Sudoku-like puzzle was printed in a French newspaper in 1895 and was devised by a Swiss mathematician called Leonhard Euler. Just like sudoku, the puzzle included a nine-by-nine grid where the numbers one to nine could only be used once in each box that made up rows, columns and diagonal lines. Later, in 1979, Dell Magazines printed the first version of the number puzzle that has the exact rules of today's sudoku.

Sudoku is referred to by its Japanese name

NEXT ISSUE
ISSUE 175
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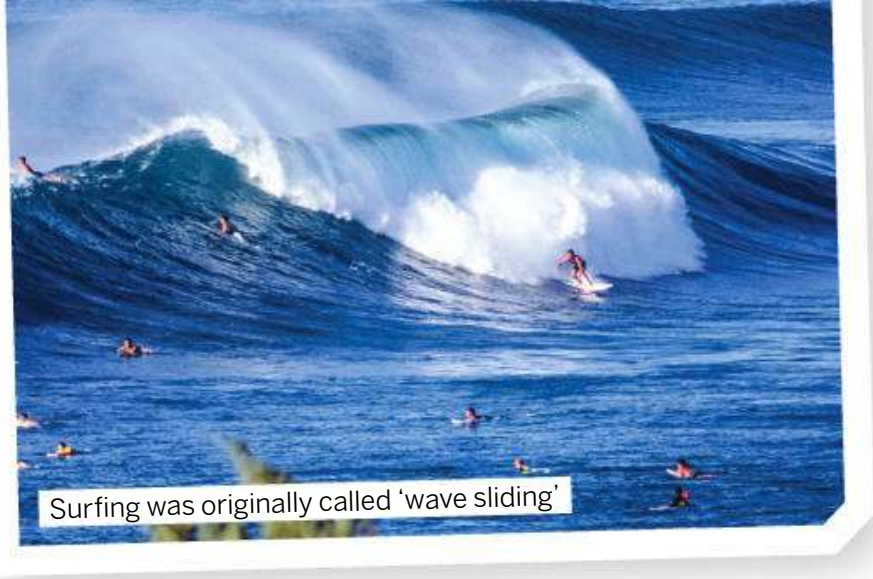

Surfing was originally called ‘wave sliding’

RIDING THE ELEMENTS

Dear **HIW**,
What came first out of skateboarding, snowboarding and surfing? Did one inspire the others, or was it a case of different communities evolving the sports separately?
Nathan Jenkins

Out of these three similar-looking sports, surfing can be traced the furthest back. From at least 400 CE, Polynesians used surfing as a way of life. Polynesian islanders were experts at navigating the ocean. Their boats helped them island-hop and create new homes, while surfing was a way to demonstrate the power of their connection with the ocean. Tahitians and Samoans would practise surfing before a battle, and it later became a method to measure strength, athleticism and superiority.

One garlic clove has 5 to 18 milligrams of allicin

SMELLY EATING

Dear **HIW**,
For foods like garlic, what is the chemical or substance in it that gives it such a strong taste? Also, how can you remove the aftertaste of garlic?
Will Nexhip

Garlic cloves have a strong chemical compound called allicin in them. When you cut into garlic with a knife or your teeth, more of this is released. After eating garlic, the lingering taste can be neutralised by eating foods such as apples and lettuce, both of which drastically decrease the compound’s concentration.

WE ASKED YOU

This month on social media, we asked you: What’s the most extreme weather you’ve experienced?

@CYRUSTHEVIRUSYEETER

Chambord Castle in France with Scouts, it was hailing and lightning

LAUREN KOUTNY

One year it snowed so much that it covered half of my front door

SAM BERRY

I have been on runs where the wind practically stopped me moving

@RAK.MALIGE

Sun, hail, rain, snow and sun again in a few hours. Also, temperatures dropping to -20 in minutes

JULIE REES

In the US when there was a heatwave over 40 degrees Celsius

© Getty

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Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Production Editor **Nikole Robinson**
Senior Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Group Editor-in-Chief **Tim Williamson**

Contributors
Rob Jones, Andrew May, Joanna Wendel, Jennifer Nalewicki, Ben Turner, Teresa Pultarova, Laura Geggel, Brandon Specktor, Elizabeth Howell

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Advertising
Media packs are available on request
Account Manager **Hayley Brailey-Woolfson**
hayley.baileywoolfson@futurenet.com
07934 357861
Advertising Director **Matt Johnston**
matthew.johnston@futurenet.com
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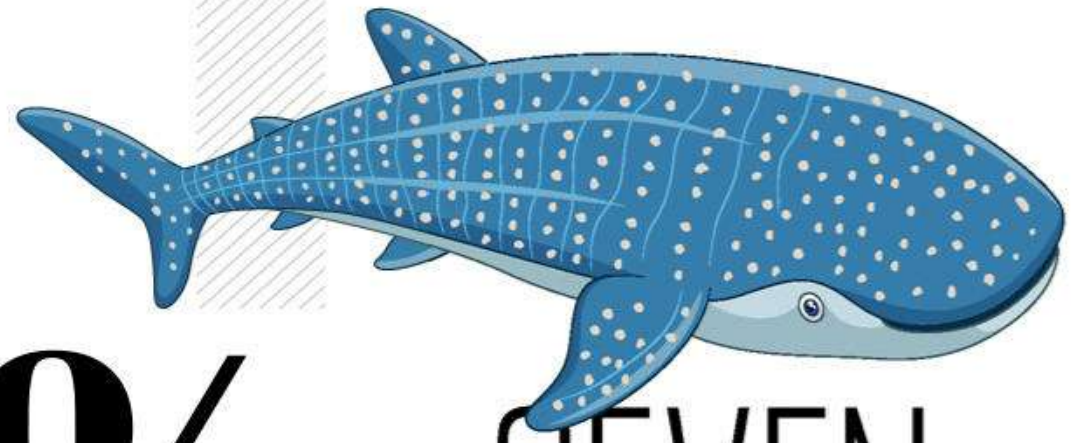
FAST FACTS

Amazing trivia that will blow your mind

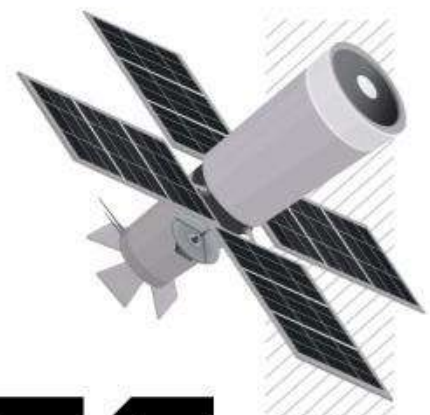


29,899 KILOWATTS

Japan's Fugaku supercomputer uses more power than 100 fridges

2%

Only a fraction of the matter in the universe is visible



SEVEN TONNES

Whale sharks can weigh as much as a double-decker bus

123456

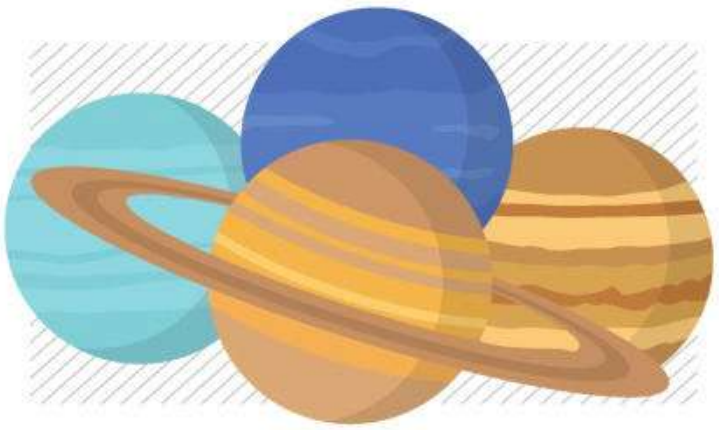
The most common password for PCs and social media accounts

In quantum physics, present-day observations can change events in the past

7 OCTILLION

There are more atoms in your body than stars in the observable universe

POUND FOR POUND, YOUR BONES ARE STRONGER THAN STEEL



JUPITER, SATURN, NEPTUNE AND URANUS ARE GAS PLANETS WITH NO SOLID SURFACE

620 MILES

Polar bears can smell their prey from a huge distance away

$5.3 BILLION

The next generation of US presidential aircraft will cost over $2 billion each

96%

Most of your body mass is made of oxygen, carbon, hydrogen and nitrogen

© Getty

IF I HAD SOMEWHERE TO LIVE...

I COULD GO ANYWHERE IN LIFE

When Abi's mum died, life got tough. She didn't get on with her dad and the arguments became violent. Abi felt her only choice was to leave home. With just the clothes on her back, and no idea where to go, she ended up sleeping on the streets in the freezing cold.

Right now, you could give a homeless young person like Abi somewhere to start their future

Abi's life changed when she was given a room at Centrepoint. A safe place to sleep and recover. A place to develop the skills and confidence she needed to rebuild her life – and leave homelessness behind for good. Now, Abi believes she can go anywhere.

Thousands of homeless young people like Abi are desperately trying to find their place in the world – but first they need a place to start again. **You could help right now by sponsoring a room at Centrepoint for just 40p a day.**

We know this support changes lives. 88% of the young people we help move on positively in life. So please, help someone like Abi today. Thank you.

Text PLACE to 78866 to donate £3
Call free on 0800 472 5798
Visit centrepoint.org.uk/place
Or complete and return the form below

SPONSOR A ROOM. HELP A HOMELESS YOUNG PERSON FIND THEIR PLACE.

YES, I WANT TO SPONSOR A ROOM FOR £12 A MONTH

Please collect my payment on the 1st/15th of every month (please circle preferred date).

Instruction to your Bank or Building Society to pay by Direct Debit

To the Manager:
Name and full address of your Bank or Building Society:

Originators Identification No. 6 5 9 1 0 7

_____ Postcode _____

Name(s) of Account Holder(s) _____

Bank Sort Code: ☐☐-☐☐-☐☐ Account Number: ☐☐☐☐☐☐☐☐

Instructions to your Bank or Building Society: Please pay Centrepoint Direct Debits from the account detailed in this instruction, subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Centrepoint and, if so, details will be passed electronically to my Bank/Building Society.

Signature(s) _____ Date _____

Banks and Building Societies may not accept Direct Debit Instructions for some types of account.

Increase your donation by 25p for every £1 you donate with Gift Aid giftaid it

☐ By ticking this box I confirm I am a UK taxpayer and want Centrepoint to Gift Aid all donations I've made in the last four years and any donations I make in the future until I notify you otherwise. I understand that if I pay less Income Tax and/or Capital Gains Tax in any tax year than the amount of Gift Aid claimed on all my donations it is my responsibility to pay any difference.

Your name and address are needed to identify you as a current UK taxpayer.

Your donation will go towards funding Centrepoint's vital work with young people all year round providing accommodation and support. We sometimes use models and change the names of the young people we work with to protect their identity; however all stories are true and as told by the young person.

Full Name: _____
Address: _____
Postcode: _____ Telephone: _____
Email: _____

Thank you for donating to Centrepoint today.

We'd love to show the impact of your support and share how young people continue to need your help, through newsletters, fundraising appeals and information about events. Please let us know how best to stay in touch with you by adding your details above, and ticking the relevant boxes:

☐ **Please contact me by email** ☐ **Please contact me by phone**

Last year our supporters helped us change the lives of over 15,000 homeless young people. By letting us know we can count on you, we can continue helping young people with a home and a future.

Your privacy is key.

We promise never to sell or swap your details, and will always keep them secure. You can view our Privacy Notice in full at www.centrepoint.org.uk/privacy. You can opt out of post and change how we communicate with you at any time. Please call 0800 232320 and speak to one of our friendly team or email supportercare@centrepoint.org to do this and ask us any questions.

Please return this form to: Freepost Plus RTXY-LBEA-UTJJ, Angel Fulfilment Services Ltd, Communication Centre, Par Moor Road, Par PL24 2SQ.

Registered office address: Central House, 25 Camperdown Street, London E1 8DZ. Company no. 1929421. Registered Charity no. 292411. Housing association no. H1869. VAT registration no. 649 345 018.

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